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PRODUCT ENGINEERING

OCTOBER, 1944

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IN THIS ISSUE—

Cover Picture—Superforts to blast Japan. B-29 bombers on the assembly line at the Wichita, Kansas, Boeing plant.

Synthetic Rubbers

New, improved synthetic elastic materials, having many rubber-like properties and embodying special characteristics not inherent in natural rubber, have been developed during the war years. These compounds: Buna S, Buna N, Butyl, Neoprene and Thiokol have substituted for rubber and have,

because of superior properties, replaced rubber in many wartime applications. In this issue, pages 681 to 696, is presented a 16-page editorial summary of these materials. Engineering properties and applications are stressed, and numerous illustrations show specific uses in modern machinery.

Mono-Gyro Stabilizer

A tiny gyro-stabilizer is the factor which permits tank gunners to fire accurately despite the lurching movement of the tank. Design highlights of the electro-hydraulic system are described by the inventor in an article on page 649. It is predicted that use of the same principles will provide "floating" rides in fast peacetime trains and automobiles.

Epicyclic Gearing

Many inventors are wasting time trying to develop an infinitely variable-speed drive by hooking together an epicyclic gear train and a conventional mechanical type variable-speed transmission. Why the hoped for results cannot possibly be achieved is clearly explained in the article beginning on page 653 which proves the case for any conceivable arrangement.

Engineering Standards Systems Reduce Design Costs and Routine

Standards are playing an important role in every phase of industrial activity. As time goes on more concerns are becoming standards-conscious. Arnold Reuss, engineering department, Koehring Company, see page 670, tells how the use of standards lowers engineering and production costs, and how standards help to increase worker productivity by providing accepted methods for design approach.

Fine-Pitch Gears

In an effort to eliminate many misconceptions involving fine-pitch gears, an article on page 697 is devoted to developments in machinery used to produce such gears. Manufacturing processes, inspection and fundamental design requirements are reviewed. Increased use of large and small precision gears in military equipment demonstrates that the designs of many postwar products will include fine-pitch gears.

Catalog Information

Designers and draftsmen working on aircraft have been plagued by a lack of the right kind of information in vendors' catalogs. In fact, the need for more and better catalog information has been considered of sufficient importance to warrant special study by the National Aircraft Standards Committee. See page 679 for the results of this study, including a listing of the essential information that aircraft manufacturers feel should be included in all catalogs.

Follower Mechanisms

With the increasing use of power-operated controls there have been numerous developments in the design of follower mechanisms for synchronizing the displacements of the manual control and the element controlled. On pages 702 and 703 are shown the five types of mechanisms generally used.

Forming Laminated Plastic Sheet

Necessity for lightweight, strong material for many aircraft parts has stimulated the development of a simple, inexpensive forming method applicable to thermosetting laminated sheet. Slight modification of the sheet by the various manufacturers to improve hot-forming qualities at low pressures resulted in a material that has many possibilities. Hard wood dies can be used for the simplest parts in quantities up to 5,000 parts. Included in an article starting on page 674 are the characteristics of the material, illustrations showing the design of many parts, and a brief description of the forming method.

Surface Finish Designation

A distinctive symbol has been adopted by North American Aviation, Inc., to designate on drawings the limiting roughness values for the surfaces indicated. James A. Broadston, armament engineer of North American, discusses use of the symbol in an article beginning on page 704, and describes simple shop inspection methods for checking surface roughness of parts.

Undercuts in Place of Fillets Simplify Cylindrical Grinding

A sequel to the article "Cost of Parts Finished by Grinding is Reduced by Correct Design" which was published in the September number. S. H. Neady, assistant chief engineer, Landis Tool Company, see page 707, tells how production can be increased and shop costs decreased by observing a few simple rules when designing sharp corners, reliefs and fillets at the inside corners of shoulders to be finished by grinding.

Effect of Temperature On Properties of Plastic Sheets

Graphs giving effects of temperature on the stress-strain and tensile properties, also on the modulus of elasticity and yield stress of cellulose acetate and cellulose nitrate sheets. See Reference Book Sheets, pages 719 and 720. Values plotted were derived from tests made by the Plastics Division, Monsanto Chemical Company.

WHAT'S COMING—

Postwar Product Designs

Alert to the importance of improving efficiency and useful life of products and in keeping manufacturing costs at a minimum, engineers are planning to adapt many new materials and techniques in postwar designs. Developments along such lines are already on many drawing boards. PRODUCT ENGINEERING editors are now procuring specific engineering information on new product developments. In the November number, the Wartime Designs section will be succeeded by a monthly section of Postwar Product Designs—16 pages replete with picture-caption analyses of the engineering details of new products for civilian use.

Aircraft Electrical Systems

Electrical units in fighting and bombing aircraft must meet rigid requirements of lightness in weight, minimum dimensions, high efficiency and reliability in operation. Research and development work among engineers of the Wright Field Materiel Command, electrical manufacturers and airplane companies has resulted in notable progress during the past few years. In a forthcoming issue, Lt. Col. T. B. Holliday, Jr., Chief of the Electrical Section, Materiel Command, Army Air Forces, summarizes developments.

PRODUCT ENGINEERING
OCTOBER, 1944

Electro-Hydraulic Stabilizer Keeps Tank Gun at Fixed Elevation

Design details of the mono-gyro control are revealed by the inventor and an associate. System consists principally of gyro-motor, silverstat contacts and bellows assembly to compensate for lurching and pitching of tanks. Use of gyro-stabilizer in peacetime trains and automobiles is predicted.

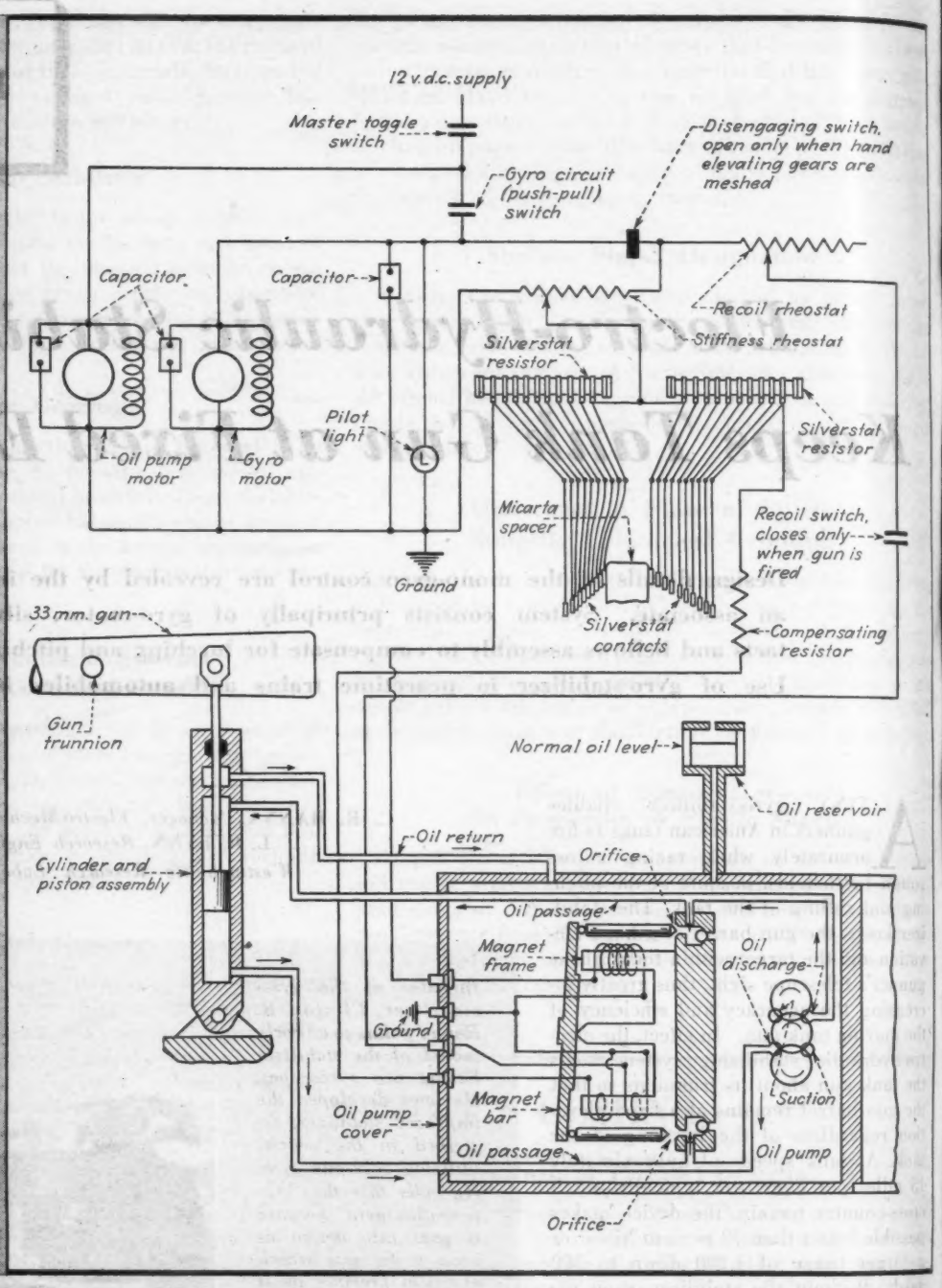
C. R. HANNA, *Manager, Electro-Mechanical Department*
L. B. LYNN, *Research Engineer*
Westinghouse Research Laboratories

A TINY gyro-stabilizer enables gunners in American tanks to fire accurately while racing across rough battlefields, in spite of the pitching and rolling of the tank. The stabilizer keeps the gun barrel at a fixed elevation and the target within focus of the gunner's telescope sight, thus greatly increasing the accuracy and efficiency of the moving tank gun. In effect, the electro-hydraulic stabilizing system floats the tank gun about its trunnions so that the gun barrel remains at a fixed elevation regardless of the lurching of the tank. At tank speeds of approximately 15 miles per hour over typically rough cross-country terrain, the device makes possible better than 70 percent hits over a target range of 1,200 down to 300 yards. Without the stabilizer, even experienced gunners were unable to score 1 percent hits under similar conditions. This ability of American tanks to shoot accurately on the run gives a tremendous advantage over enemy tanks which must ordinarily stop to fire.

The same principles that enable American tanks to fire on the run with much deadly effect promise to provide "floating" rides in high-speed trains and other vehicles. Calculations show, for example, that only about three horsepower are needed to stabilize the vertical movement of a railroad coach. Stabilizer power and size vary as the mass and the square of the fluctuations. Thus, an automobile and a railroad car would require units of about the same size since the excessive vertical vibration of an automobile compensates for its lightness. The railway and automotive fields are merely typical of possible applications of the general principles of the stabilizer since such principles are applicable wherever stability is required in a member of a body in motion.

Inventor of the gyro-stabilizer, Clinton R. Hanna points to an early model of the stabilizer having two gyroscopes. He later developed the improved stabilizer, described in the article, utilizing only one gyro. He calls this the "Anticipating gyro" because it goes into action as soon as the gun breech exercises pressure on it and corrects for movement before it can take place. The Westinghouse engineer won a citation from the WPB for this invention, which permits Army tanks to fire accurately while in motion.

The four basic components of the gyro-stabilizer system used for tank guns are (1) the gyro motor, (2) the silverstat regulator, (3) the oil pump system including the electro-magnetically controlled valves, and (4) the piston and cylinder assembly. The gyro control tends to maintain the tank gun fixed in its aimed position. Tank fluctuations tending to alter this position precess the gyro which, through the silver-



Cycle of operation. Pitching of tank tilts axis of rotation of gyro flywheel causing precession, that is, an angular movement about the vertical axis in proportion to the velocity of pitching. This causes movement of micarta spacer, closing silverstat contacts, and thereby cutting out resistors and changing current flow to magnets. Unbalance of magnetic pulls increases opening of one orifice, thus causing drop in hydraulic pressure in that leg of circuit, and decreases the opening of the other orifice, thus causing increased hydraulic pressure in that leg. Thus the hydraulic piston swings the gun about its trunnion at an angular speed proportional to pitching of the tank, and maintains the gun in the same absolute elevation.

stat, varies the current to the electromagnet valves. The valves are affected in such a fashion that the oil pressure above and below the piston increases and decreases in accordance with the signal current. Since the piston is fixed to the gun, its movement to the low pressure side maintains the gun in the aimed position.

Mono-Gyro Control

The latest development of the tank gun stabilizer is the mono-gyro control. This system has but a single gyro which controls the silverstats through its response to angular velocity and through its slight gravity response. The gravity response is effected by an offside unbalanced weight which causes a slight deflection of the silverstats in the proper sense whenever the gyro is tilted from vertical, and a gradual return to vertical occurs.

The mono-gyro control, consisting principally of the gyro-motor, the silverstat control, and the bellows assembly, is only slightly influenced by an acceleration or sharp turning of the tank. The gyro has a gradual and approximate return to the aimed position. The gyro motor is a 12-volt direct current machine for light tanks or a 24-volt direct current for medium tanks, operating between 12,500 and 16,000 revolutions per minute. The perfectly balanced flywheel is mounted on frictionless bearings. Attached to a bracket on the motor, a micarta spacer opens and closes the silverstat contacts as the gyro moves on its bearings. The silverstat has two sets of 10 leaves which connect to taps on resistors. The current through the magnetic coils on the oil pump valves can thus be regulated by making and breaking silverstat contacts. The bellows assembly is attached to the gyro control base and is connected to the gyro with piano wire. It hydraulically damps the gyro to prevent resonance about the vertical precession axis and returns the micarta spacer to its correct position between the silverstat leaves.

The gyro has only one degree of free-

dom about a vertical axis and precesses against a spring centering through an angle which is proportional to the angular velocity of the gun about its trunnions. Since the mono-gyro control does not have an absolute vertical reference, the gun may not always return to its exact starting point when it is disturbed. However, this apparent lack of accuracy is unimportant because the gunner is required to aim the gun continuously anyway by handwheel rotation of the gyro unit relative to the gun.

Actually, power aiming is obtained in the same simple manner and through the same controls that cause stabilization. The gyro unit is so attached to the gun that it may be rotated by means of a handwheel, flexible shaft, and worm gear. The rate of turning the handwheel, affects the gyro member just as angular velocity of the gun; the gunner aims the gun by precessing the gyro in accordance with his rate of turning; and the stabilizer tends to maintain the gun in its aimed position. Any very slow drifting caused by lack of an absolute vertical reference is thus readily compensated by the gunner himself.

Any angular displacement of the gun arising from tank motion will tend to displace the gun-mounted gyro control from its position. When the tank pitches or vibrates, (1) the gyro control is slightly displaced from its former vertical position (2) the resulting precession of the gyro makes electrical contacts, shorting resistances through the silverstat, (3) the changed current alters the two electro-magnets regulating the teeter valves, (4) the operation of the oil valves decreases the pressure on one side of the hydraulic piston and increases the pressure on the other side, (5) the piston is forced toward the low pressure side, and (6) the movement of the gun is controlled accordingly since the piston is fixed to the gun.

Auxiliary Control Used

The recoil of the gun barrel after firing results in large gravity unbalances. To prevent the violent disturbances which this would cause, an auxiliary control is provided: A micro-switch closes when the gun recoils and furnishes current to an auxiliary magnet recoil of the valve in a manner to supply supporting pressure for breech heaviness during recoil. The recoil adjustment need not be precise because the gyro control through its silverstat regulation of the other magnet coils compensates for any remaining slight differences.

In the development of the stabilizer, it was found that the principle disturbances average 1½ cycles per second corresponding to the pitching frequency of the tank on its springs, while angular velocities are about 30 deg. per secnod and accelerations about 300 deg. per second squared. The rather great inertia of the gun barrel is a favorable element, for if balanced and unhindered the gun would remain at a constant angle. Moreover, as the tank pitches, the comparatively small trunnion friction would give only low angular accelerations of the gun; and relatively close balancing of the mass about the trunnions would minimize the acceleration torques arising from the vertical and horizontal movements of the tank.

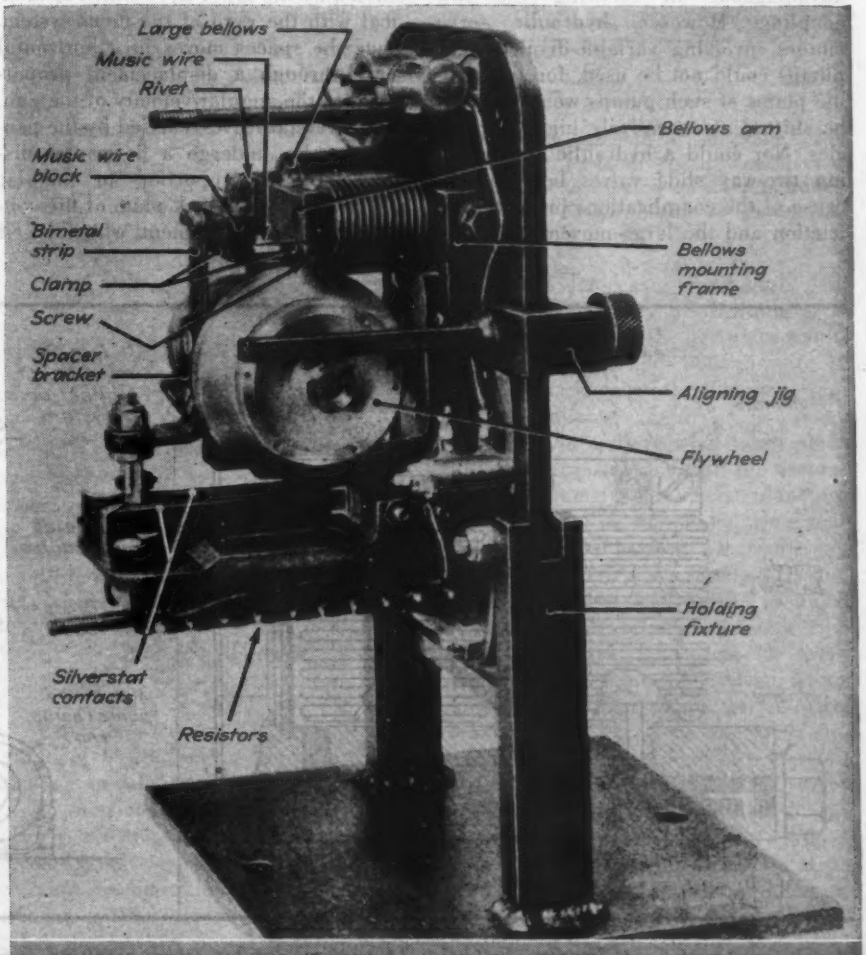
Actual field conditions, however, are severe because of considerable oscillations, dust, moisture, and wide temperature ranges. In addition, the cramped and limited tank turret space imposes simplicity and compactness on the design of a stabilizer.

The stabilizer not only satisfied field conditions but surpasses original requirements. The Ordnance Department had requested that disturbances of ±2½ deg. at 1½ cycles per second for the tank, typical fluctuations over average rough terrain, should be reduced to ±⅓ deg. error at the gun. The stabilizer as developed exceeded these specifications by about 3 to 1—that is, disturbances of ±2½ deg. at 1½ cycles per second result in less than ±⅛ deg. gun error instead of the specified ±⅓ degrees.

Servo Mechanism System

A power means is used for stabilizing the tank gun rather than a gyroscope large enough to resist the disturbing torques directly. Because the required accelerations are excessive, an electric motor for keeping the gun at a fixed angle of elevation is impractical. High angular accelerations can be obtained with an electric motor drive, but the unit would be too large for the limited, available turret space.

The servo mechanism in use is a composite hydro-electric system having two constant displacement pumps, one for each end of the hydraulic cylinder. The pressure difference for the pumps is controlled by a pair of seated by-pass



Mono-gyro control in assembling fixture showing relative positions of the gyro, silverstat, and bellows assembly. Gyro motor and gyro are mounted pendulous with the silverstat. Bellows unit dampens the gyro oscillations.

valves regulated by the teeter bar armature of an electro-magnetic unit. The entire assembly, including the magnetic valve-control device is oil-immersed. The double pump utilizes three spur gears running at constant speed. The discharge from each pump normally passes through one of the seated valves. If, however, a valve is partially closed by a differential pull of the magnetic coil, the pressure increases, forcing oil into the cylinder supplied by that pump. Since the magnet valve is encased within the pump of the hydraulic system, the operation is free of friction. Furthermore, since a very small movement of the valves immediately provides any proportion of the constant flow from the pumps, the operation of the system is instantaneous for all practical purposes.

The system develops torques equal to the combined disturbing torques from all coupling members. The cylinder, valves, and connecting pipes are designed to give relatively small coupling between tank and gun in order to minimize the additional disturbance from this source. The use of a high-pressure low-delivery hydraulic system is highly advantageous in securing the low coupling. However, hydraulic servo motors involving variable-displacement pumps could not be used, for the wobble plates of such pumps would have to be shifted at excessively high frequencies. Nor could a hydraulic system using two-way slide valves be used because of the complications presented by friction and the large movements.

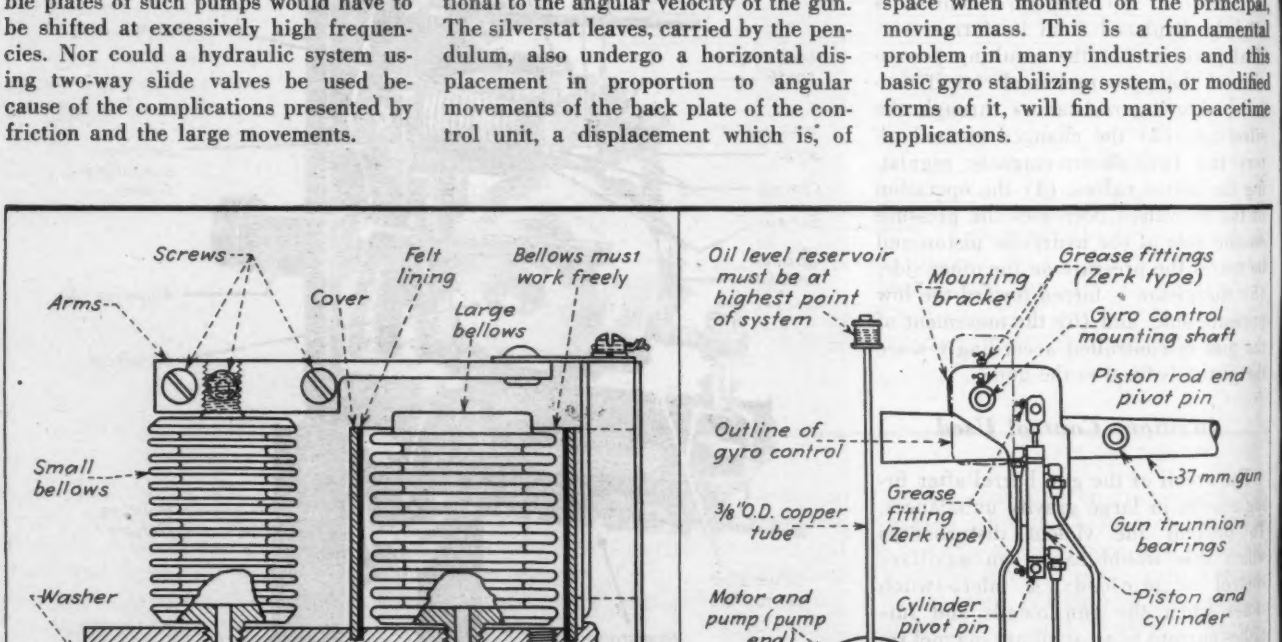
Double-Gyro Control

The present mono-gyro control was developed from the original type of stabilizer which utilized two gyros, an upper and a lower one. The upper gyro in this system provided an absolute vertical reference. It is a slightly pendulous, double-gimballed gyro co-operating with a single plane pendulous member mounted on separate bearings which have their axis parallel to the gun trunnions. The pendulous member is so coupled to the gyro through friction shoes and a bearing plate that the gyro seeks a vertical and is highly damped in its conical oscillations. When the pendulous member is off vertical, the friction plate presses against one of the gyro shoes, precessing the gyro about its right angle axis. The precession is accompanied by sliding friction in proportion to the precessional velocity. This method of damping allows the gyro and pendulum to return completely to vertical since the friction is zero.

The silverstat regulator is mounted on the pendulous member. The micarta spacer between the silverstat leaves is carried by the lower gyro which is identical with the gyro of the mono-system. Thus the spacer moves in a horizontal sense through a displacement proportional to the angular velocity of the gun. The silverstat leaves, carried by the pendulum, also undergo a horizontal displacement in proportion to angular movements of the back plate of the control unit, a displacement which is, of course, equal to the lever angle of the gun. The silverstat is thus actuated in proportion to angular velocity and angular displacement of the gun by means of the two gyroscopes.

It was discovered, however, that satisfactory stabilization could be obtained by using only the velocity responsive gyro. With the dual system, the response of the upper gyro to lateral accelerations was so pronounced that firing was accurate only at fairly uniform tank velocities. Aside from the advantage of simplicity in omitting one of the two gyros, the response of the mono-control system to lateral accelerations was greatly reduced. Since the gunner must continually aim the gun, the slight drift in the mono-gyro system is unimportant.

Even before the development of the tank gun stabilizer, gyros of the velocity type were in use. In 1939 Colonel David J. Crawford, Ordnance Department, U. S. Army, had visited the Westinghouse Research Laboratories with a group from the War College and had seen certain regulatory devices involving gyroscopic anti-hunting elements. The principles involved in the stabilization of the tank gun as well as in the anti-hunting devices are essentially the same. In general terms, the result is the stabilization of a component mass with respect to space when mounted on the principal, moving mass. This is a fundamental problem in many industries and this basic gyro stabilizing system, or modified forms of it, will find many peacetime applications.



(Left) Construction of damping bellows. Adjustment needle valve determines amount of damping. The essential feature is that the damping is accomplished with practically no friction. (Right) Schematic diagram shows relations of stabilizer parts. Gyro control, containing tiny gyro, gyro motor, silverstat regulator, and bellows, is mounted on gun barrel. Gun fluctuations resulting from pitching and rolling of the tank precess gyro, contacting silverstat leaves and sending changed current to magnet valves in oil pump. The electro-magnetic valves and oil pump are inclosed in oil sump of the hydraulic system. Change in valve position alters the oil pressure in the cylinder, moving the piston and hence the gun.

Limitations of Epicyclic Gearing For Variable-Speed Drives

J. F. ALLEN
Engineer, The Warner & Swasey Company

What takes place when power is transmitted through an epicyclic gear train combined with a mechanical type variable-speed transmission is explained by a simple analysis. The fundamental power, speed and efficiency curves, applicable to any size, type and arrangement of such a transmission are established, showing the possibilities and limitations of a variable-speed drive.

THERE is a pressing need for variable-speed transmissions capable of transmitting greater power than can be handled by the available mechanical type transmissions and able to operate over ranges of speed greater than the 6 to 1 ratio or 8 to 1 ratio of the available variable-speed transmission. For example, the machine tool builders would like to be able to obtain 50 hp. transmissions covering a 60 to 1 speed range.

Many inventors working on this problem have attempted to solve it by the use of an epicyclic gear train. It is quite simple to obtain an infinite range of variable speeds through the use of an epicyclic gear train in combination with a conventional variable-speed transmission. Fig. 1 shows such an arrangement. Although any range of variable speed ratios is obtainable with such an arrangement, the drive has insurmountable limitations that make it unusable for transmitting high powers over wide speed ranges.

Any one of three units of the epicyclic gear train can be driven at constant speed, and either of the other two at variable speed. Usually the sun gear is driven at constant speed and the ring gear is constrained to rotate at a selected variable speed by means of the variable-speed mechanical transmission. Thus the speed of the output shaft, to which the planetary gear spider is keyed, can be controlled over a range of speeds from zero to maximum. Even reverse rotation can be obtained.

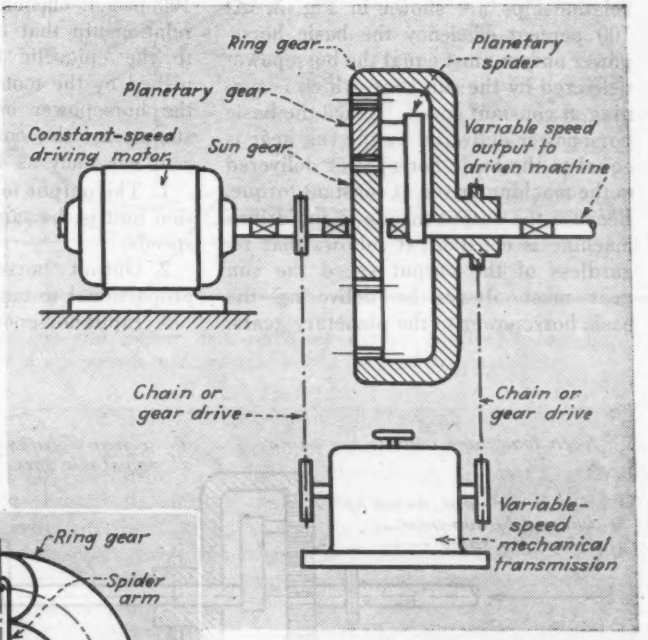


Fig. 1—Arrangement of epicyclic gear train and variable-speed mechanical transmission by which an infinite range of variable output speeds is obtainable.

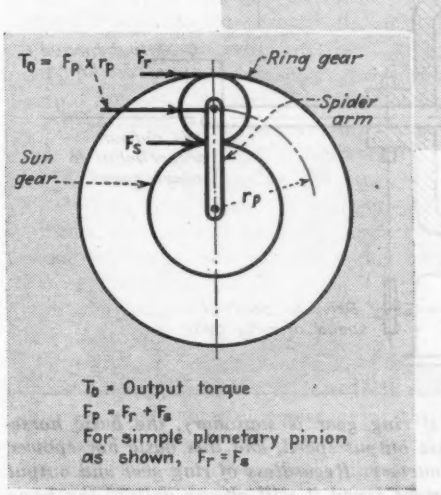


Fig. 2—Different gear ratios and gear arrangements will affect the magnitude of the tooth loads, but for any given epicyclic transmission the output torque establishes all the tooth loads throughout, regardless of speeds. If output torque is constant, any given tooth load will be the same for all speeds.

As may be expected, there are certain practical limitations in the application of such an infinitely variable-speed epicyclic transmission. Because these limitations are not apparent, innumerable inventors have been led astray. To determine the limitations of such a transmission it is necessary to analyze what takes place when power is transmitted through it.

The epicyclic transmission with the variable-speed mechanical transmission can be considered as a single unit. The mechanical efficiency of the unit as a transmission will be the horsepower output divided by the horsepower input. At 100 percent efficiency these horsepowers would be equal.

In order to analyze what takes place within the transmission unit the various elements, namely, sun gear, planetary gears mounted on the spider, ring gear and the variable-speed transmission, must be considered separately. To simplify the analysis it will be assumed that the driven machine requires a driving torque that is the same for every speed of the output shaft. That is, we are dealing with a constant torque drive.

As shown in Fig. 2, for any given epicyclic train the tooth load at every pair of meshing gears will be determined by the torque on the output shaft of the epicyclic transmission. This follows from the fact that in any gear train, regardless of the gear ratios or arrangements, the torque on any one of the elements of the transmission determines each of the tooth loads throughout the train.

To simplify the explanation further,

all conditions that exist when the ring gear is stationary will be called "basic." The basic conditions will be analyzed on an assumption of 100 percent efficiency.

When the ring is stationary, the output of the epicyclic transmission will be called the basic horsepower and the speed of the output shaft will be called the basic speed. The speed and power relationships are shown in Fig. 3. At 100 percent efficiency the basic horsepower output must equal the horsepower delivered by the sun gear, which is running at constant speed. Hence the basic horsepower delivered by the sun gear is equal to the basic horsepower delivered to the machine driven at constant torque. Because the output torque to the driven machine is constant, it follows that regardless of the output speed the sun gear must always be delivering the basic horsepower to the planetary gears.

If the ring gear is now rotated, or allowed to rotate, the output speed of the epicyclic transmission will change accordingly. But as already stated, the sun gear is driven at constant speed the horsepower delivered by the sun gear is always the same regardless of the output speed of the unit and is always equal to the basic horsepower.

Continuing with the assumption of 100 pecent efficiency, we also have the relationship that the horsepower input to the epicyclic transmission as furnished by the motor is always equal to the horsepower output. We can now summarize the conditions at 100 percent efficiency as follows:

1. The output torque of the transmission unit is the same at all output shaft speeds.

2. Output horsepower is therefore proportional to output shaft speed.

3. Input horsepower, that is the horsepower delivered by the motor, is always equal to the horsepower output of the transmission unit.

4. The speed of the sun gear is constant and its tooth load is constant.

5. Therefore the horsepower delivered by the sun gear is constant and always equal to the basic horsepower, regardless of output speed.

Obviously the difference between the basic horsepower delivered by the sun gear at any output speed and the horsepower delivered by the unit or the driving motor at that output speed, must be accounted. The answer is, as shown in Fig. 4, this horsepower difference at output speeds below the basic speed is delivered by the sun gear to the ring gear through the medium of the planetaries, is then transmitted through the mechanical variable-speed transmissions, then back to the motor shaft and back to the sun gear.

The magnitude of this "circulating horsepower" is directly proportional to the difference between the basic output speed and the running output speed. When the output speed is "basic," no horsepower circulates, the ring gear being held stationary. At zero output speed the full basic horsepower must circulate if the torque is maintained on the output shaft.

To obtain output speeds above the basic speed, as shown in Fig. 5, the ring gear must be driven in the reverse direction relative to its rotation at output speeds less than basic speed. The flow of the power is reversed, that is, the motor shaft drives the ring gear through the mechanical variable-speed transmission.

This analysis applies regardless of gear ratios employed, speed ranges, horsepower magnitudes, direction of rotation or arrangements of the gears. The relationships presented above are fundamental and inflexible.

The concept of a "circulating power"

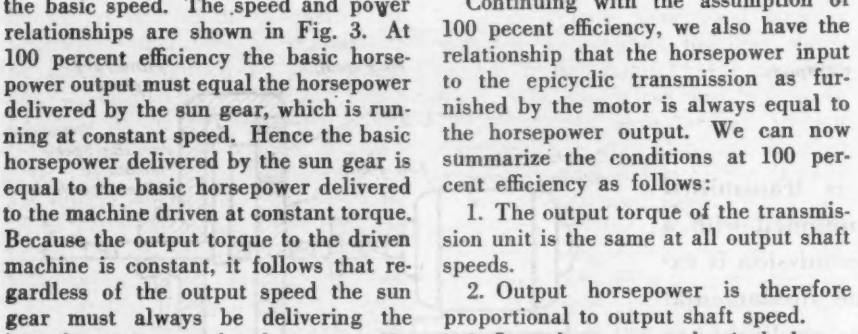

Tooth loads are always the same
Ring gear rotates at adjustable speed
r.p.m. is constant, hence hp. delivered by sun gear is always the same
Output torque is constant
Hp. output proportional to output speed
Variable-speed transmission
Drive to control speed of ring gear

Fig. 3—Assuming 100 percent efficiency, if ring gear is stationary, the basic horsepower output will be delivered at the basic output speed, and this basic horsepower will be delivered by the sun gear to the planetary. Regardless of ring gear and output speeds, with the sun gear running at constant speed it will always deliver the basic horsepower to the planetary gears as long as the output torque remains the same.

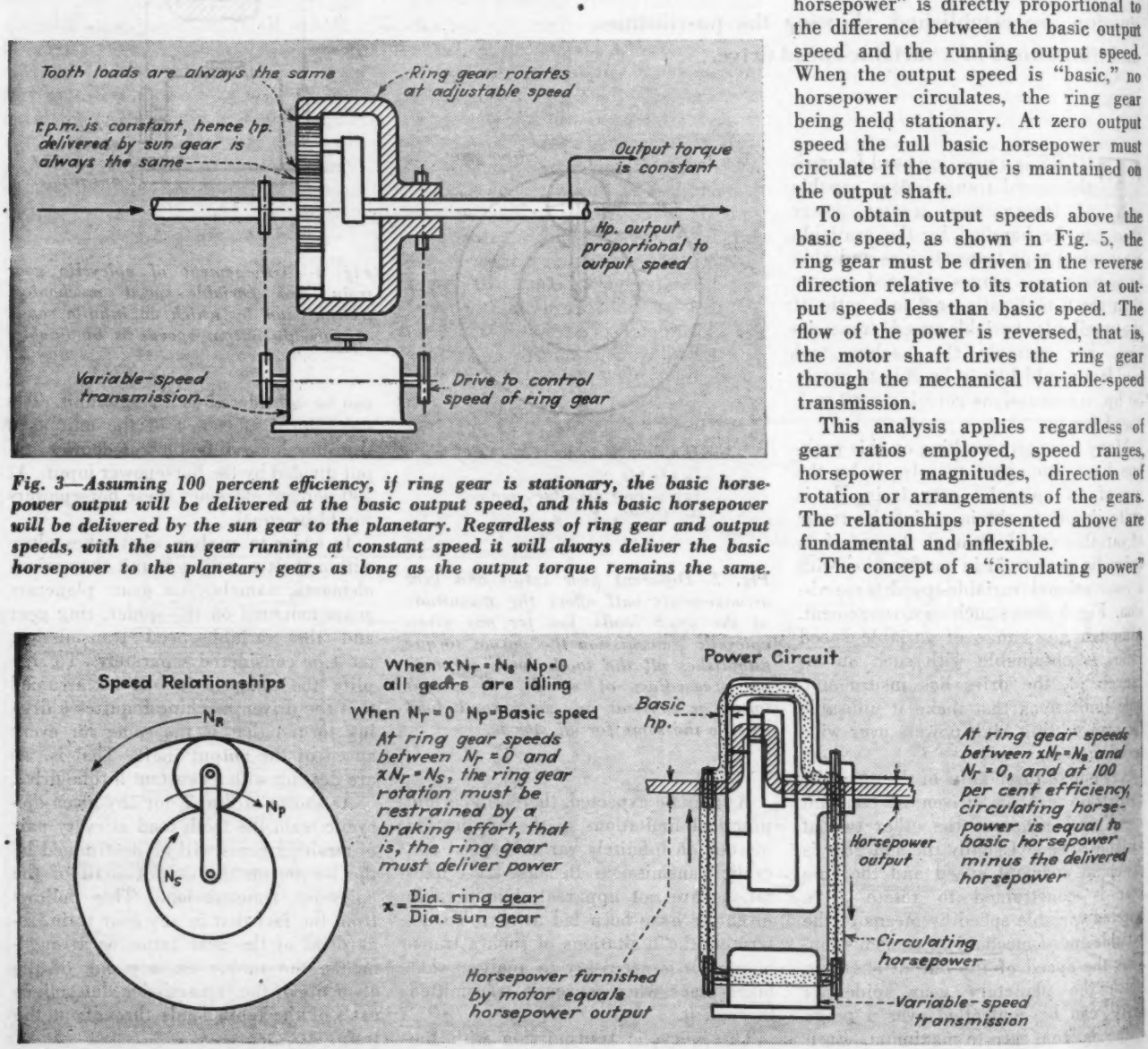

Speed Relationships
N_R
N_P
N_S
When $\chi N_r = N_s$ $N_p = 0$ all gears are idling
When $N_r = 0$ N_p = Basic speed
At ring gear speeds between $N_r = 0$ and $\chi N_r = N_S$, the ring gear rotation must be restrained by a braking effort, that is, the ring gear must deliver power
$\chi = \frac{\text{Dia. ring gear}}{\text{Dia. sun gear}}$
Power Circuit
Basic hp.
Horsepower output
Circulating horsepower
Horsepower furnished by motor equals horsepower output
Variable-speed transmission
At ring gear speeds between $\chi N_r = N_s$ and $N_r = 0$, and at 100 per cent efficiency, circulating horsepower is equal to basic horsepower minus the delivered horsepower

Fig. 4—Speed and power relationships at output speeds below basic speed

is admittedly unorthodox and therefore may be difficult to accept. By definition, power is the rate of doing work. No work is being done by the "circulating power" and hence one may argue academically, it is not power. A more realistic picture of what takes place can be obtained by inserting in the path of the "circulating power," energy conversion units. The following demonstrates such an arrangement.

If the ring gear is completely free to rotate, no torque will be transmitted by the epicyclic transmission. A braking effort must be applied to the ring gear to prevent such free rotation. In the arrangement shown in Fig. 1, the braking effort is furnished by restricting the speed of the ring gear by connecting it to the sun gear shaft through a mechanical variable-speed transmission and other gearing. The braking effort could be obtained, equally well, by any other means such as connecting the ring gear to a brake or to a generator.

Assume that an electric generator is used to slow the ring gear. The electric generator is loaded by furnishing the current generated to an auxiliary motor mounted on the sun gear shaft which in turn delivers the energy back to the ring gear. With this arrangement one can readily visualize the "circulating power." An ammeter in the circuit would indicate the flow of power. Thus the concept of "circulating power" is not fiction but a reality. Power actually is circulated and thereby must incur the power losses associated with the type of power transmission system employed.

The fundamental curves for the epicyclic variable-speed transmission operating at constant torque output are easy to construct and reveal the limitations of such a unit. Referring to Fig. 6, any ordinate at a suitable distance along the X-axis serves as the "basic speed ordinate." Any convenient point on this ordinate is chosen to represent the basic horsepower. A straight line from the origin *O* and passing through the basic horsepower point will represent the horsepower output at corresponding output speeds. A straight line from the base of the basic speed ordinate to the point on the Y-axis representing basic horsepower, will be the curve of circulating horsepower. A symmetrical straight line to the right of the basic speed ordinate will be the curve of power furnished by the motor to the ring gear, through the variable speed transmission.

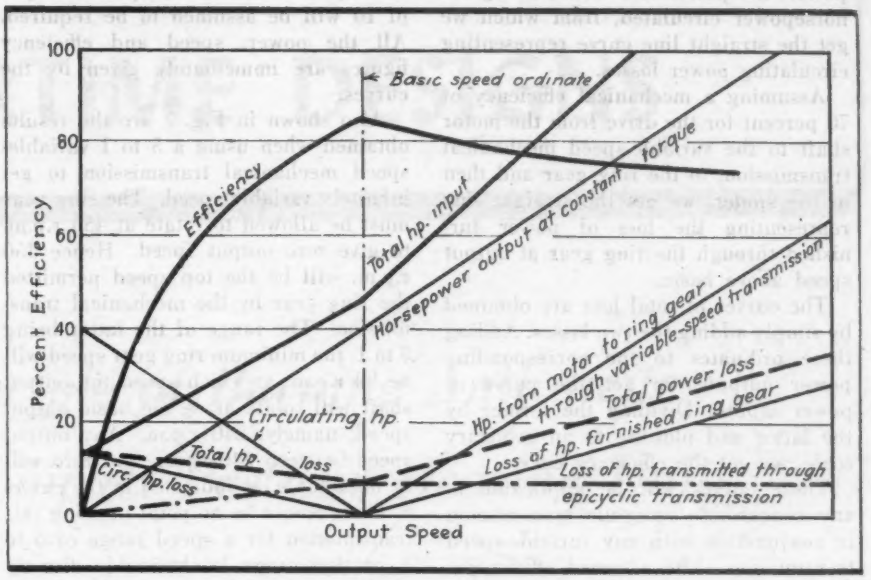


Fig. 6—Fundamental power and efficiency curves applicable to any size or arrangement of epicyclic variable-speed transmission.

Power losses in the transmission arise from three sources. From zero to basic output speed, about 15 percent of the horsepower input that is delivered through the sun gear and planetary spider to the output shaft, is lost. This is a conservative estimate based on gear efficiencies of 95 percent. In terms of horsepower output, this loss amounts to horsepower output divided by 0.85 and minus the horsepower output, or 0.176 times the horsepower output. Multiplying the scalar distance representing basic horsepower by 0.176 gives the Y-value of the point on the basic speed ordinate representing this friction loss in the power transmitted through the sun and planetary gears at basic speed. Connecting this point to the origin *O* gives the curve of transmitted power loss for all speeds below basic.

At all speeds above basic, only the basic horsepower is delivered through the sun and planetary gears. Hence to the right of the basic speed ordinate the curve of loss for this phase of the power is a horizontal line.

Assuming an efficiency of 66⅔ percent for the path of the circulating

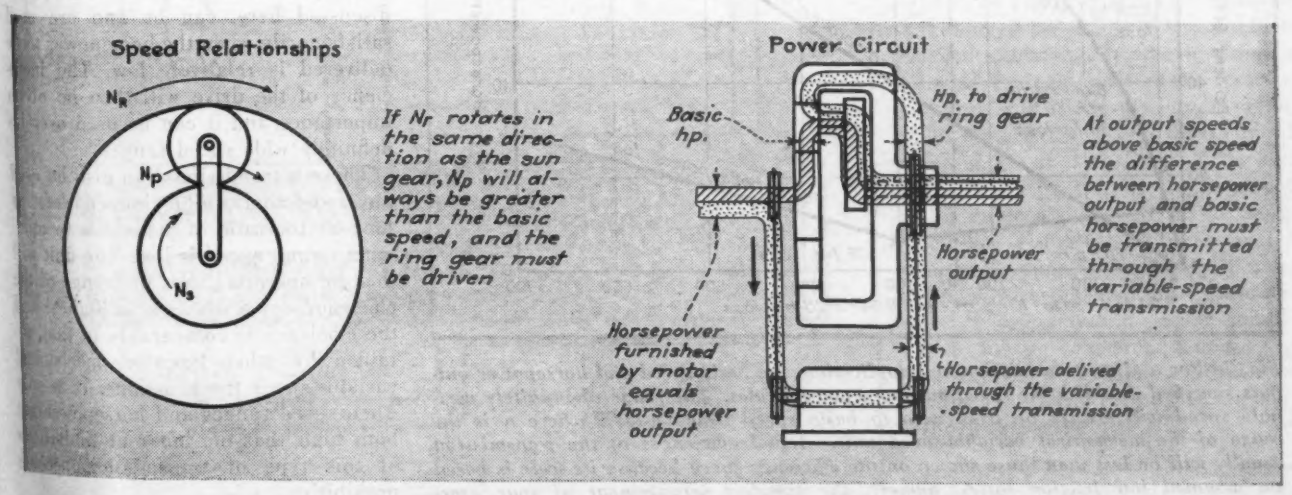

Speed Relationships
N_R
N_P
N_S
If N_R rotates in the same direction as the sun gear, N_P will always be greater than the basic speed, and the ring gear must be driven
Power Circuit
Basic hp.
Hp. to drive ring gear
Horsepower output
Horsepower furnished by motor equals horsepower output
Horsepower delived through the variable-speed transmission
At output speeds above basic speed the difference between horsepower output and basic horsepower must be transmitted through the variable-speed transmission

Fig. 5—Speed and power relationships at output speeds above the basic speed

power, the power loss would be ⅓ the horsepower circulated, from which we get the straight line curve representing circulating power losses.

Assuming a mechanical efficiency of 70 percent for the drive from the motor shaft to the variable-speed mechanical transmission, to the ring gear and then to the spider, we get the straight line representing the loss of power furnished through the ring gear at output speed above basic.

The curves of total loss are obtained by simply adding the two losses. Adding these ordinates to the corresponding power outputs we get the curve of power inputs. Dividing the former by the latter and plotting to an arbitrary scale, we get the efficiency curve.

These curves will be applicable to any conceivable epicyclic transmission in conjunction with any variable-speed transmission. The assumed efficiencies are for the simplest arrangement. For more complicated epicyclic trains such as with stepped spider gears, the efficiencies will be lower. Hence the curves represent about the best results obtainable.

To apply the basic curves to any specific transmission it is merely necessary to determine the basic speed and basic horsepower output. This immediately gives the speed scale and the horsepower scale. Fig. 7 shows the curves applied to a 900 r.p.m. motor driving through a 2-1 epicyclic gear train, giving a basic output speed of 300 r.p.m. A basic horsepower output of 10 will be assumed to be required. All the power, speed and efficiency figures are immediately given by the curves.

Also shown in Fig. 7 are the results obtained when using a 5 to 1 variable-speed mechanical transmission to get infinitely variable speed. The ring gear must be allowed to rotate at 450 r.p.m. to give zero output speed. Hence 450 r.p.m. will be the top speed permitted the ring gear by the mechanical transmission. The range of the latter being 5 to 1, the minimum ring gear speed will be 90 r.p.m. at which speed the output shaft will rotate at ⅘ the basic output speed, namely, 240 r.p.m. Any output speed between 240 r.p.m. and zero will be obtainable, as indicated in the curve.

There would be no point in using this transmission for a speed range of 6 to 1, as that range is obtainable directly by a conventional transmission. For a 24 to 1 speed range the operating efficiency at minimum output shaft speed, as shown by the curves, is only 9 percent and for a basic horsepower of only 10 the horsepower loss is 3.28 hp. This power loss must be dissipated as heat. The heat energy equivalent to 3.28 hp. is approximately the heat produced by three domestic-size electric flat irons. This figure would be proportionally increased for larger horsepowers outputs.

It will be noticed that for any appreciable speed reduction the efficiencies are low, at high horsepowers, the heat that would have to be dissipated is so great that the transmission unit would be impractical and costly to operate.

It will also be noticed that nothing would be gained by reversing the direction of rotation of the ring gear and operating in the field to the right of the basic speed ordinate. A five-to-one mechanical variable-speed unit could not possibly produce a much greater range of output speeds. Also, most of the horsepower output would have to be transmitted through the variable-speed transmission, thereby requiring a cumbersomely large unit.

Exception might be taken to this analysis because it is based on constant torque output. However, regardless of how the output torque may vary with speed, it will not affect the percentage distribution of the flow of power in the various paths. When the ring gear is stationary all the power from the motor to output shaft must flow through the sun gear, planetary gears and the spider. When the ring gear is rotating at the speed to give practically zero output shaft speed, power will be circulated. The magnitude of the power circulated can easily be calculated for any torque output. It will be proportional to the output torques.

For variable output torques, numerical values will of course be changed but the circulating horsepower always exists. For constant horsepower operation, output torque values are exceptionally high at low speeds and since it is at low output speeds that circulating horsepower is highest, it is obvious that constant horsepower operation would give values of circulating horsepower and power losses many times greater than those indicated by this analysis which has been confined to constant torque conditions.

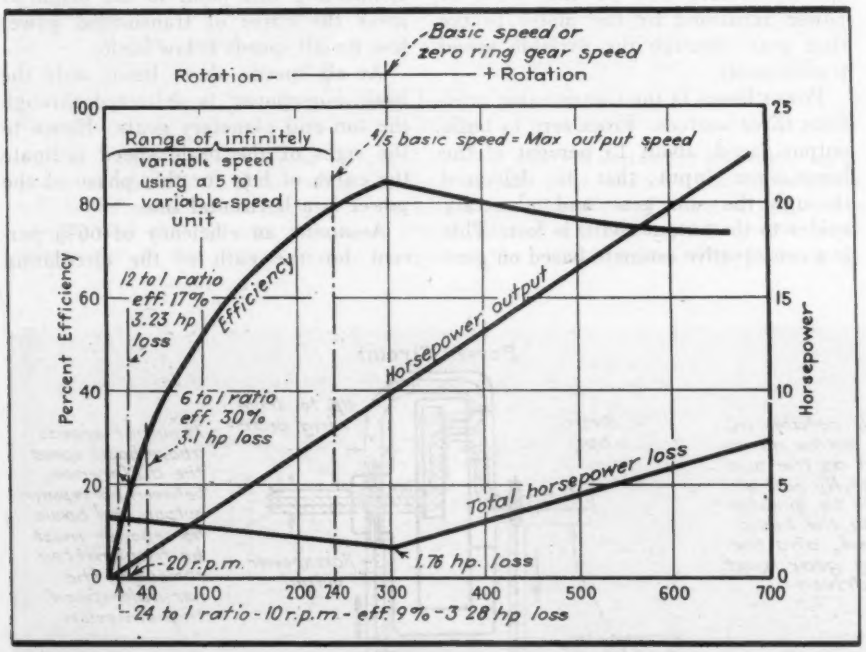


Fig. 7—For a given transmission and application, the basic speed and horsepower outputs specified establish the speed and horsepower scales. The range of infinitely variable speed will always be from zero to basic speed time (n-1)/n where n is the range of the mechanical variable-speed unit. Actual efficiences of the transmission usually will be less than those shown on the efficiency curve because its scale is based on assumed low friction losses, namely, the simplest arrangement of spur gears

Possible Uses

Epicyclic variable-speed units such as discussed here, can be and are used satisfactorily when the horsepower to be delivered is relatively low. The inefficiency of the drive will then be of no importance and it can be used over indefinitely wide speed ranges.

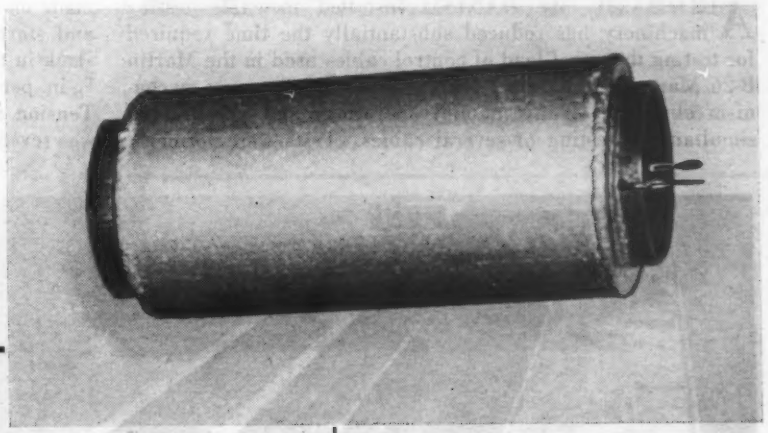
These transmissions can also be used for indefinitely high horsepowers as long as the ratio of maximum to minimum output speed is low. The unit will then be operating over the range of the efficiency curve where it is highest and the efficiency is comparable to that obtained by other types of mechanical variable-speed transmissions. It is only when speed ranges and horsepower are both high that the inherent limitations of this type of transmission become prohibitive.

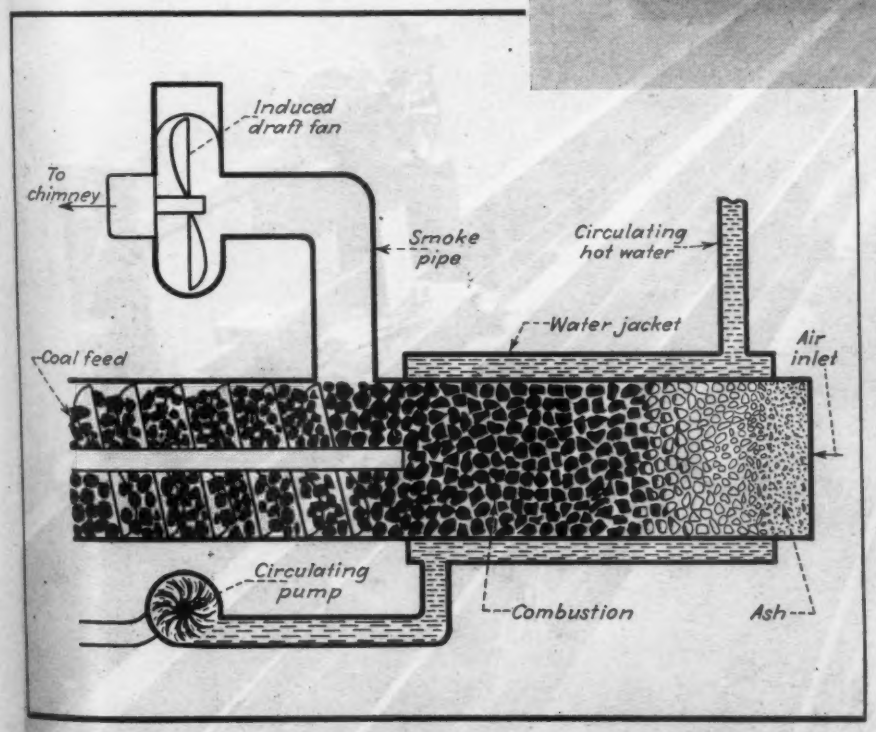
WARTIME DESIGNS

New Principle of Burning Anthracite Promises Compact Postwar Heating Units

A REVOLUTIONARY new principle of burning anthracite developed by the Anthracite Industries Laboratory substitutes a concentrated, fast-burning fire of great intensity for the former method of burning anthracite slowly in a firebox of relatively large size. Utilization of the new principle will make possible the design of automatic units, suitable for heating the average size home, that can be inclosed in a space less than 2x2x3 ft. The unit can be sold and installed for considerably less than equipment now in use for domestic fuel. Application studies are under way.

New unit is shown at right. Present home-heating equipment burns anthracite at the maximum rate of approximately 10 lb. per sq. ft. per hr. The new development burns 50 to 60 lb. per sq. ft. per hr., liberating more than 500,000 B.t.u. per cu. ft. as compared to approximately 50,000 liberated with present-day equipment. As a result, the heat absorption per square foot of heating surface is raised from 6,000 B.t.u. to 40,000 or 50,000, reducing the total amount of coal consumed.



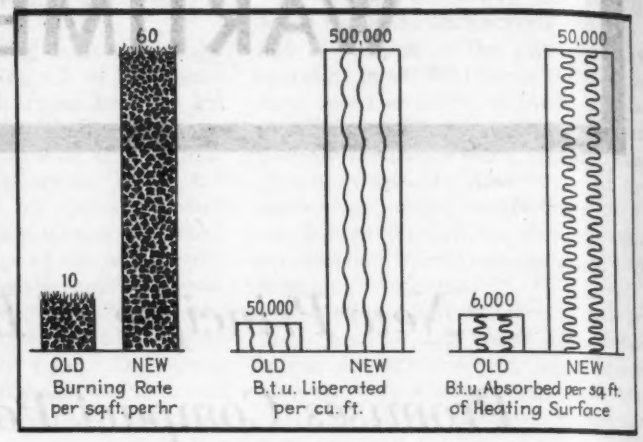


Unit consists of a hollow tube six or eight in. in diameter and approximately 18 in. long. A revolving worm introduces the coal automatically into one end of the tube. The coal burns in the center of the tube, and ash is discharged at the other end. Draft is provided by air which enters at the ash end of the tube and is drawn through the incoming coal by an induced draft fan in the smoke pipe. No secondary air or secondary combustion space is necessary, because under proper conditions anthracite burns to complete and perfect combustion within its own area. Water is circulated around the tube by a water circulator and carries the heat to the house through the outlet pipe.

(continued on next page)

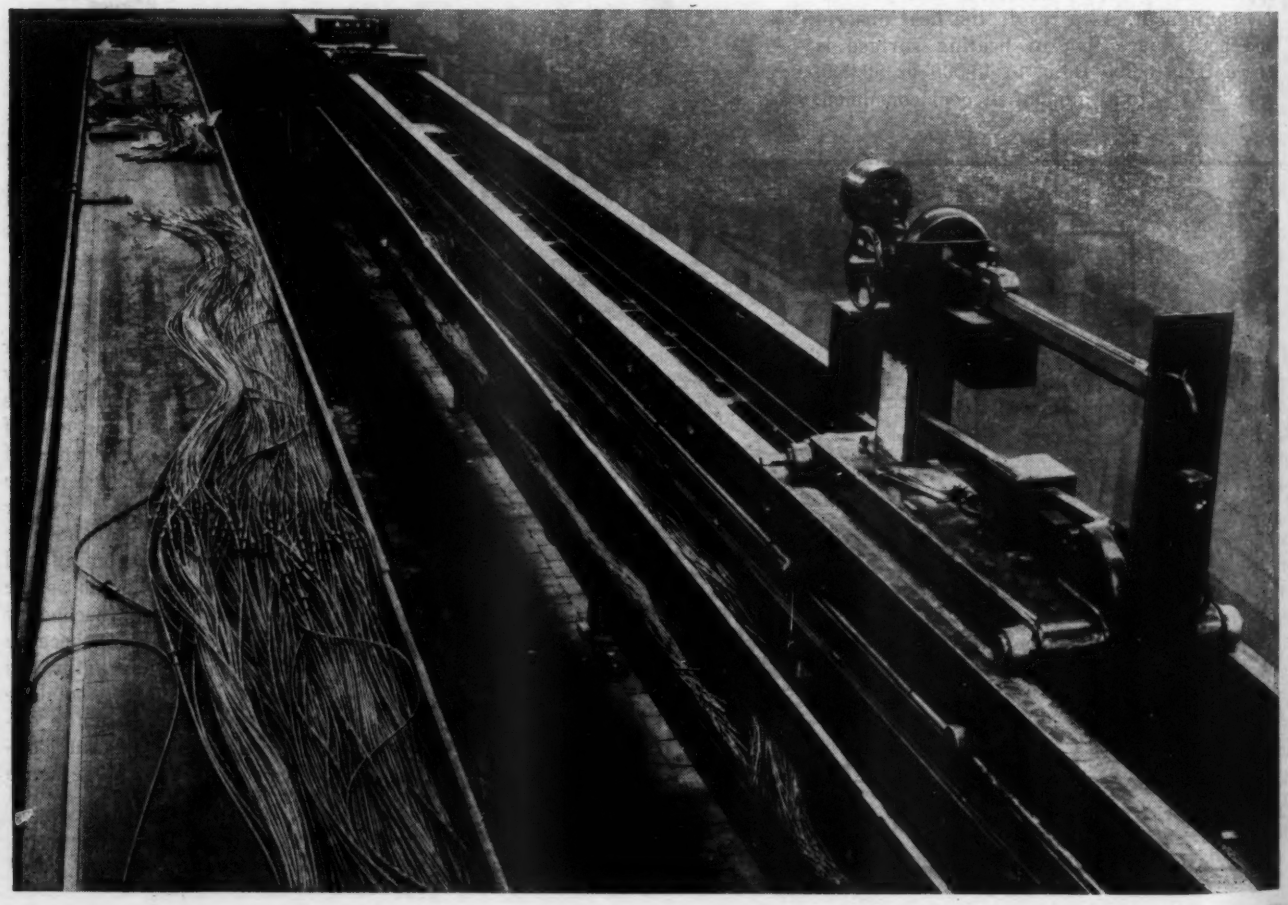
New Coal Burning Principle (continued)

Former designs of heaters had large grate areas with large combustion space above the fire bed so that the quantities of carbon monoxide which were formed could be burned above the bed with secondary air. Such equipment had several times the bulk and weight that is necessary in a furnace designed for anthracite. In the new development, the complete absence of complicated flue passes or secondary heat absorbing surfaces does not lower efficiency, because the heated products of combustion flow through the cold incoming coal to stimulate ignition and to use the coal as an economizer, replacing conventional secondary heating surfaces. The coal cannot clinker, because the small size of the fire bed permits the water surrounding the tube to carry off the heat so rapidly that the actual temperature of the burning coal is lower than the point at which clinkers form in an anthracite fire. Either hot water, steam, or warm air systems can utilize the principle.

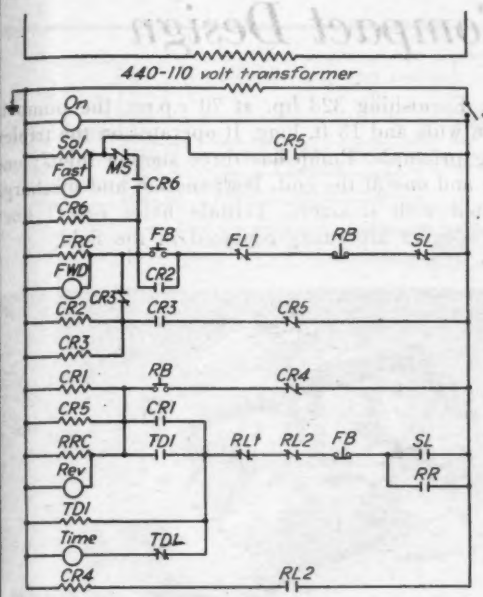


Electrical Mechanism for Cable Testing

AUTOMATIC MECHANISM installed in cable testing machinery has reduced substantially the time required for testing the proof load of control cables used in the Martin B-26 Marauder and other Martin bombers. The new mechanism eliminates many manual operations and permits the simultaneous testing of several cables. Tests were formerly made on one cable at a time. The operator inserted the cable and started the machine in fast forward motion to remove slack in the cable. The machine's speed was then reduced to 1/8 in. per min. and stopped when proper tension was reached. Tension was held for a time interval and then the machine was reversed by the operator to slacken the cable for removal.

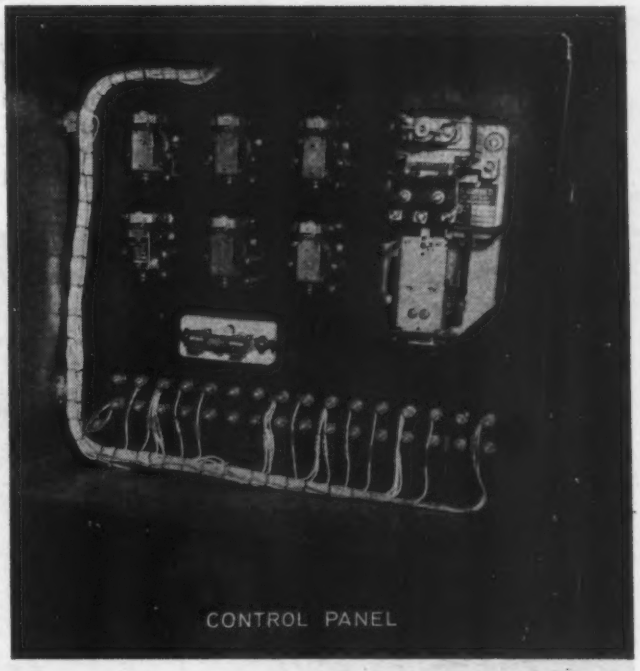


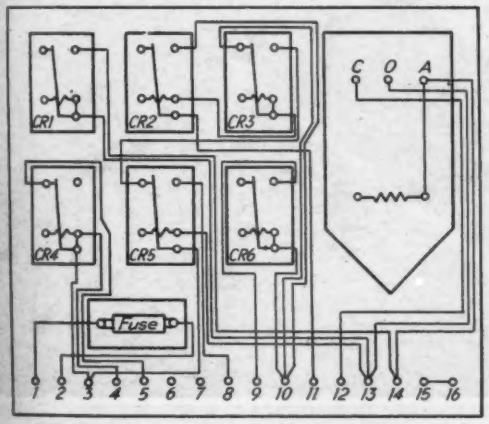
Cable Tester (continued)



LEGEND

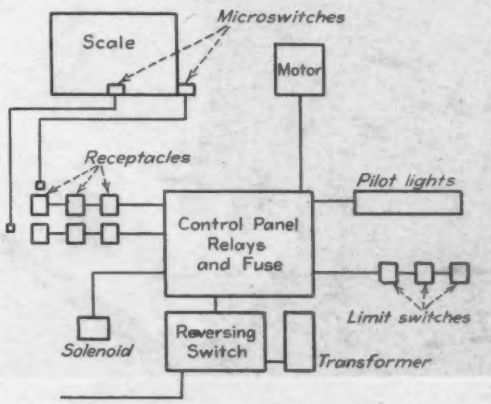
SS	Safety control switch	FL1	Forward limit
On	Controls "on" pilot light	RRC	Reverse relay coil
Sol	110 volt solenoid	RR	Auxiliary contact on reverse relay
MS	Microswitch	Rev	Reverse pilot light
Fast	Speed pilot	TDI	Time delay relay
FRC	Forward relay coil	Time	Timing pilot light
FB	Forward pushbutton	FWD	Forward pilot light
RB	Reverse pushbutton	CR1	} Control relays
SL	Scale limit	CR2	
RL1	Stationary reverse limit	CR3	
RL2	Adjustable reverse limit	CR4	
		CR5	
		CR6	





NOTE: Left-hand end of all coils are wired to neutral terminals No. 15 or 16

TERMINAL NUMBER	EXTERNAL CIRCUIT
1	Hot feed from transformer
2	Feed to control switch
3	Return from control switch
4	Return from RL2
5	To RB
6	
7	
8	To solenoid
9	To MS
10	Return from FB
11	Return from FL1
12	To time pilot light
13	To reverse coil
14	Return from RL1
15	} Neutral terminals
16	



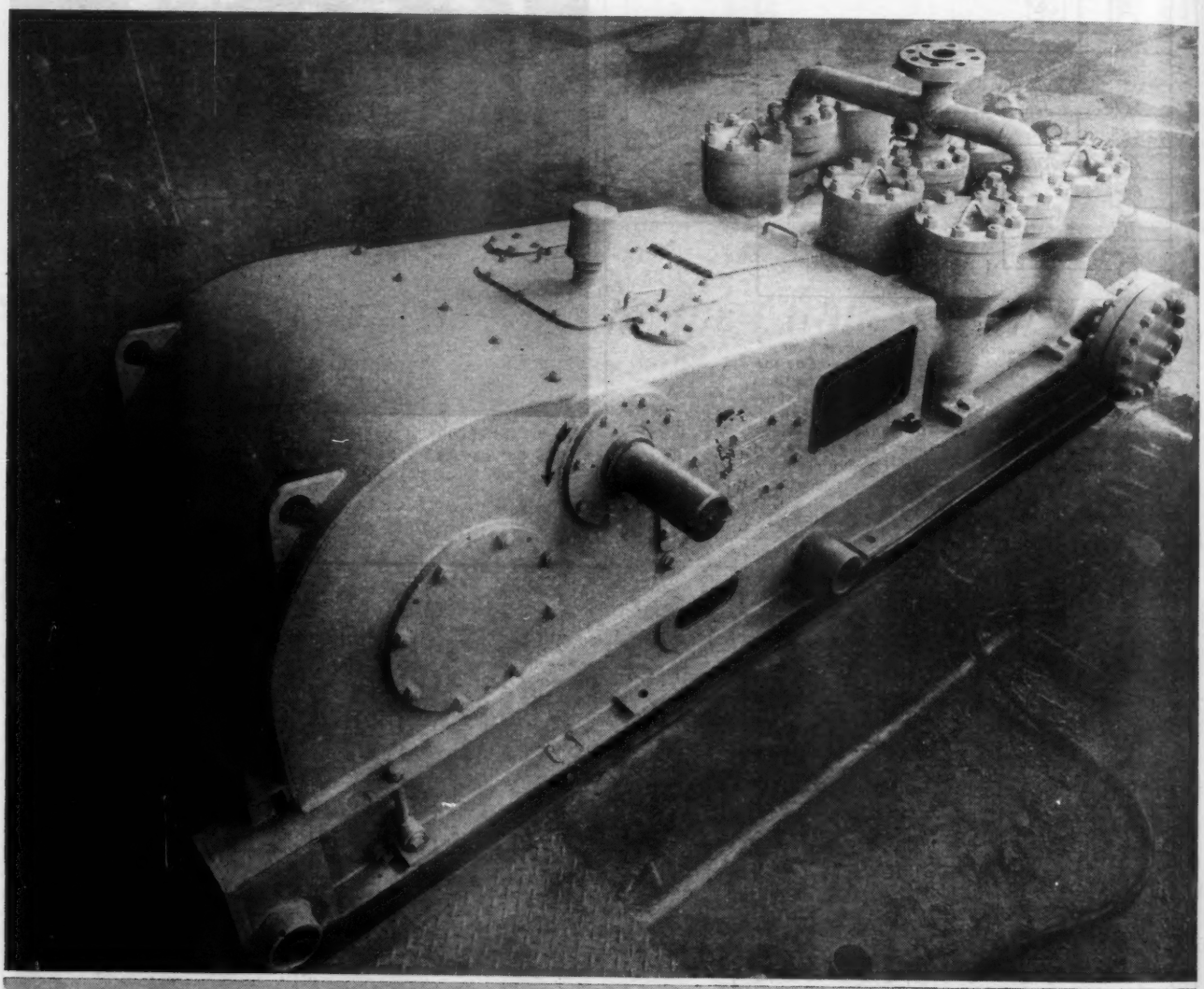
Under the new automatic arrangement, the operator places the cables, starts the machine and removes the cables after testing. All other operations are performed automatically through a system of electrical relays and limit switches. Pilot lights on a special panel indicate the machine's progress through the entire cycle, leaving the operator free to assemble turnbuckles and prepare additional cables for testing. The new test set-up has a 25,000 lb. total load capacity. The number of cables which can be tested simultaneously in the machine is limited only by the proof load required for the various types of cables.

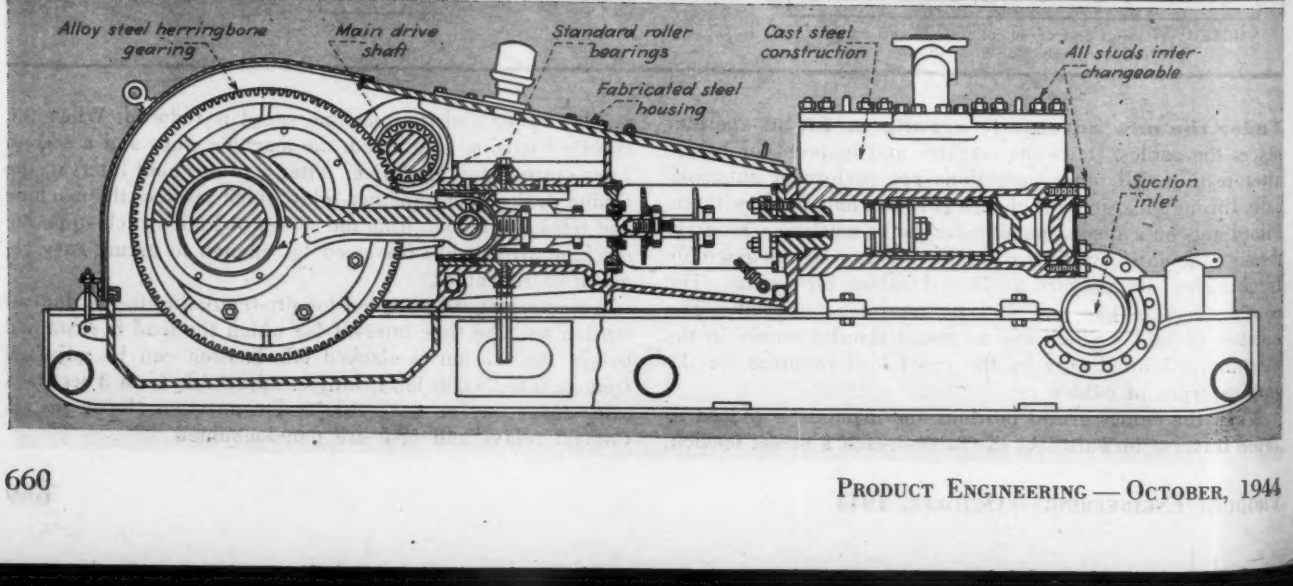
When the cables are in position, the machine is placed in rapid traverse forward. As the cables reach a preset tension, a relay opens and the machine speed is reduced. When the specified tension is attained, the machine stops and a second relay starts a timing device. After a preset hold interval, the timing device opens another relay which reverses the machine and releases the load from the cables. A limit switch stops the machine after it has traversed far enough to permit easy removal of the cables.

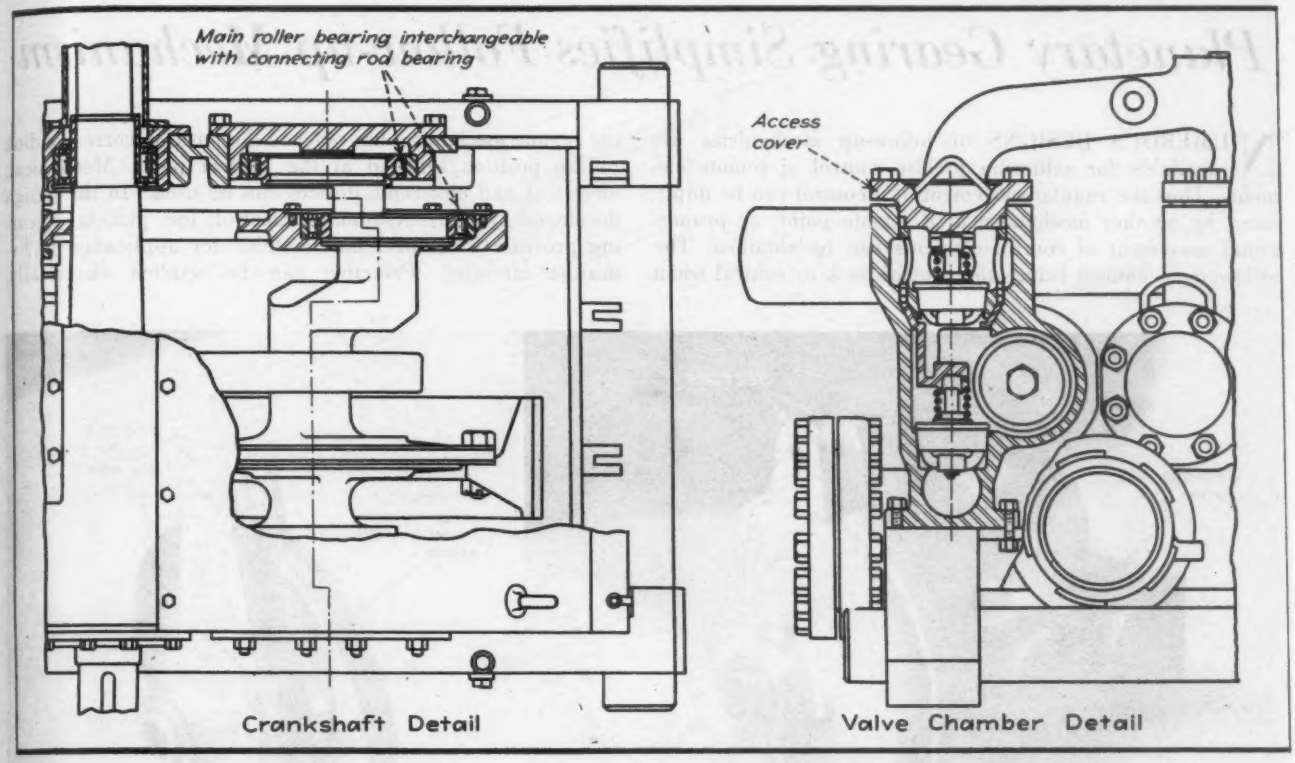
Adjustments are provided for pre-regulating the amount of tension and the time interval for which the load is sustained before the tension is slacked off. Tension can be adjusted from zero to 25,000 lb. Timing is adjustable from 3 sec. to 3 min. depending on the cable and connections being tested. Control relays and fuse are panel-mounted.

All-Steel Slush Pump of Compact Design

BASIC AIMS in the development of a new heavy-duty slush pump by Clark Bros. were to reduce weight and over-all dimensions, improve appearance, and simplify field servicing through the use of standard parts and interchangeable components. Streamlined appearance and weight reduction were obtained by combining fabricated and cast steel construction. Furnishing 323 hp. at 70 r.p.m., the pump is less than 7 ft. wide and 13 ft. long. It operates on the triplex double-acting principle. Pump has three suction inlets; one on each side and one at the end. Both suction and discharge ends are fitted with strainers. Telltale holes reveal liner leaks. Liner sleeves are easily replaced in the field.







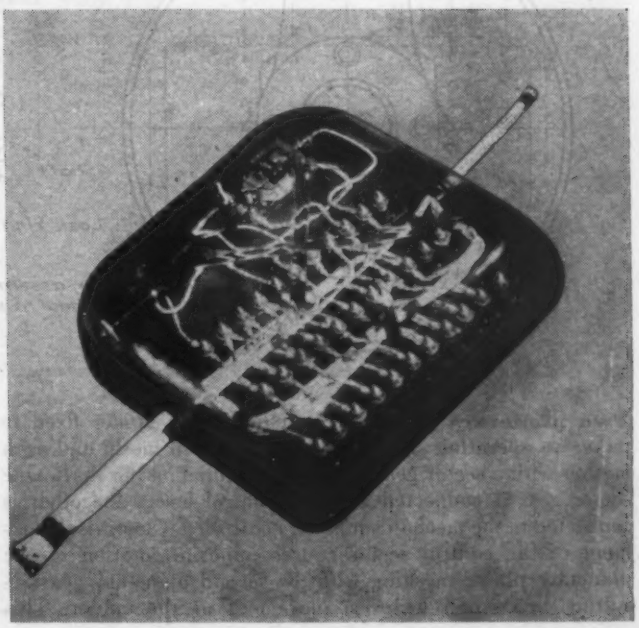
Mechanical features. Any one of the three cast steel cylinders can be replaced in the field. Crankshaft has eccentric hubs on the crank throws. Crosshead extension rod is chrome-plated. All connecting rod bearings and the main bearing at power end are interchangeable. Roller bearings are used throughout. No bolts are used in connecting rod or main bearing assemblies. All studs in the fluid end on valve pots and cylinder covers are the same size, hence interchangeable. Valves, pistons, rods and rod packing are standard make, as are roller bearings for connecting rods, main shaft, pinion shaft and crosshead pins. This was done to simplify servicing in the field. Valve over valve construction wherein both valves at fluid end can be removed through one valve cover opening, also simplifies servicing and maintenance.

Redesign in Plastic Speeds Wiring Assembly

REPLACING ALUMINUM ALLOY, a new type plastic electric junction box developed by Glenn L. Martin Co. is light in weight and easy to assemble. The new box has a flat plate to which wiring is attached. A formed cover of acrylic or other transparent plastic fits over the plate. This design makes wiring much more accessible than in the conventional junction box.

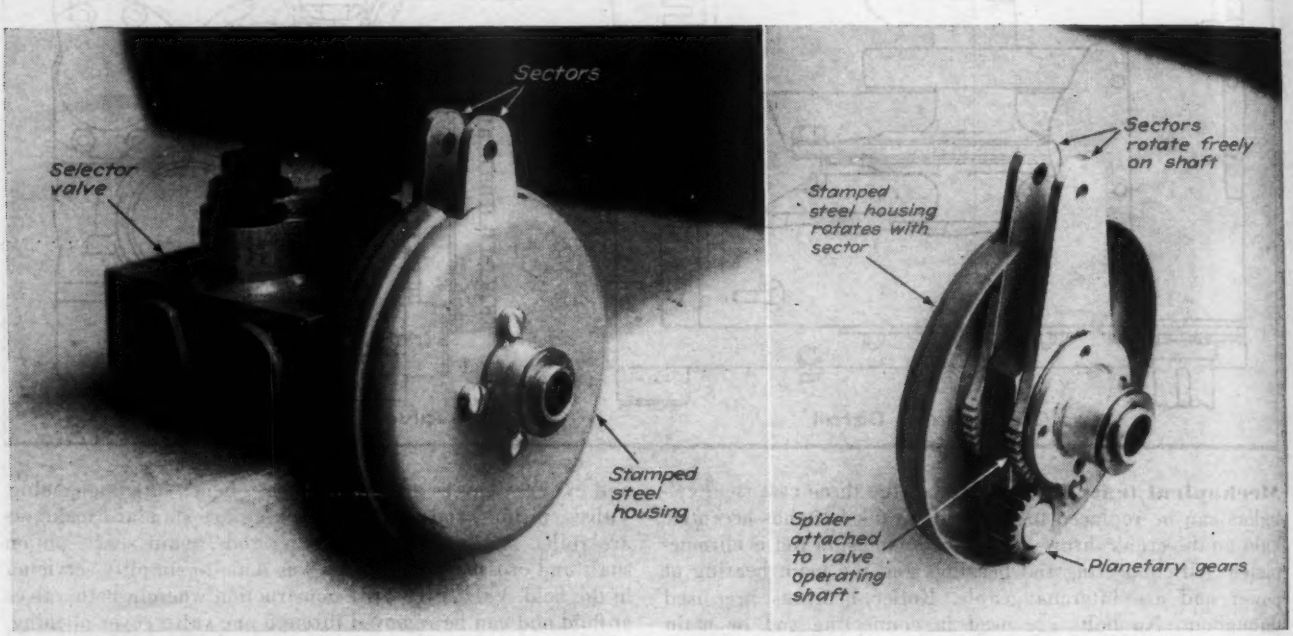
Outstanding time-saving improvement in the new design is the sensitizing of the plastic baseplate and the reproduction thereon by photographic process of the wiring diagram. This simplifies drilling, assembly and wiring of the boxes in the factory, and in addition provides a permanent record for the use of field men in servicing.

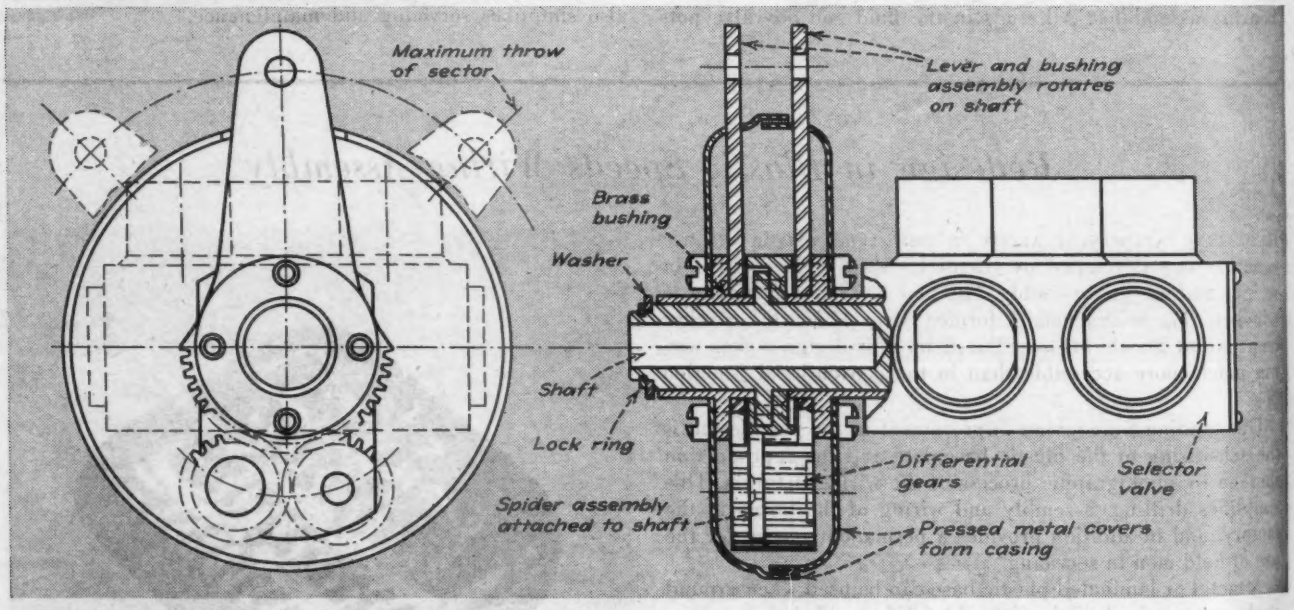
A metal or laminated plastic base can be used when ground studs are required in the assembly. The molded transparent cover requires only a single, low-cost, cavity mold. Forming is done with air from a flat sheet heated to 380 deg. F. Transparency of the cover adds still further to the man-hour savings both during manufacture and in the field. With the old-type metal box now in use in the center wing section of the PBM-3 Mariner, the cover must be removed and replaced 23 times for visual inspection between the original installation and the turning of the airplane over to ground test.



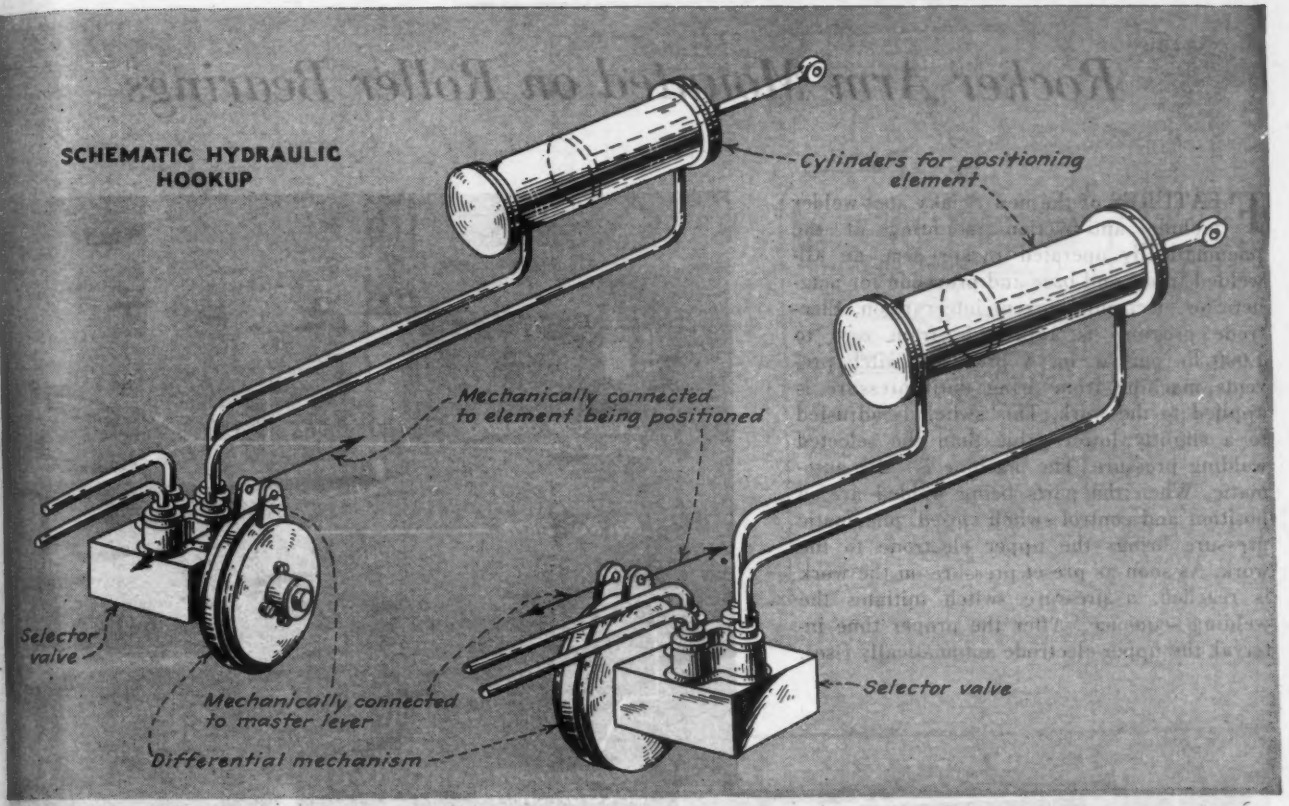
Planetary Gearing Simplifies Follow-up Mechanism

NUMEROUS DESIGNS of follow-up mechanisms are available for achieving precise control of remote elements. Thus the angular movement of a control can be duplicated by another mechanism at a remote point, or proportional movement of control elements can be obtained. The follower mechanism brings the control back to neutral when the remote mechanism has reached the position corresponding to the position selected at the control point. Mechanical, electrical and electronic devices can be used. In the design developed by B. N. Ashton, of Electrol, Inc. planetary gearing provides a compact unit suitable for application to hydraulic circuits. Principle can be applied electrically.

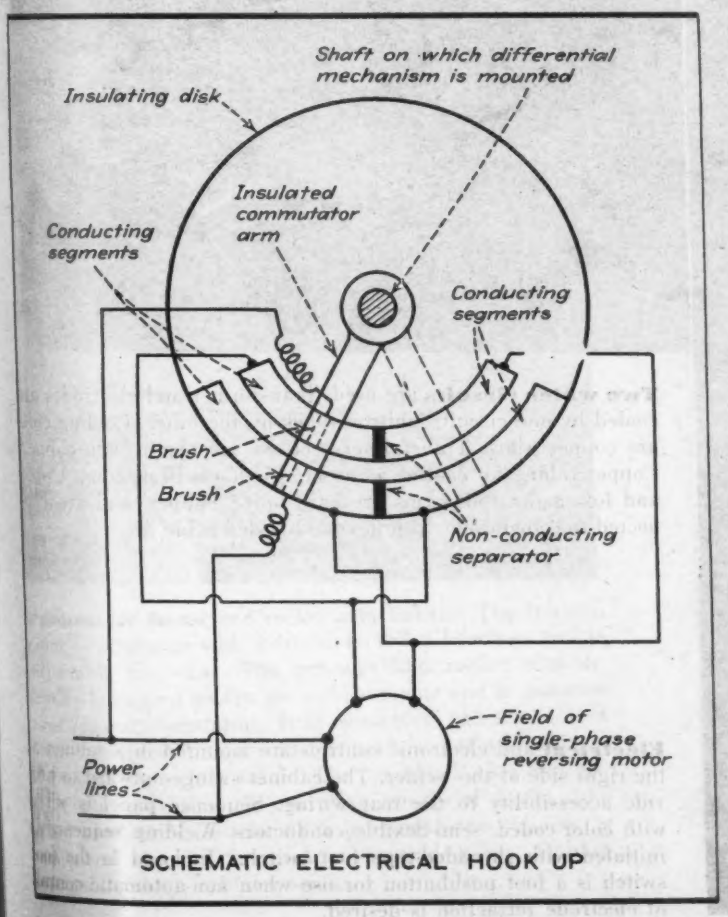




Two planetary gears are mounted on a spider fixed to the valve operating shaft. These gears are in mesh, and each meshes with a sector gear rotatably mounted on the shaft. One sector gear is connected with the control lever; the other is connected to the mechanism being controlled. Clockwise movement of the control sector causes opposite rotation of the planetary pinion meshing with the second planetary gear resulting in counterclockwise movement of the spider. This rotation opens the four-way valve, supplying fluid to the hydraulic cylinder on motor. Since the cylinder or motor being controlled is mechanically connected to the second sector gear, which also meshes with planetary gear on the spider, movement of the controlled element tends to rotate the spider clockwise so that the valve is returned to neutral, thus locking the controlled element in the pre-determined position. Entire mechanism is inclosed in stamped steel housing.



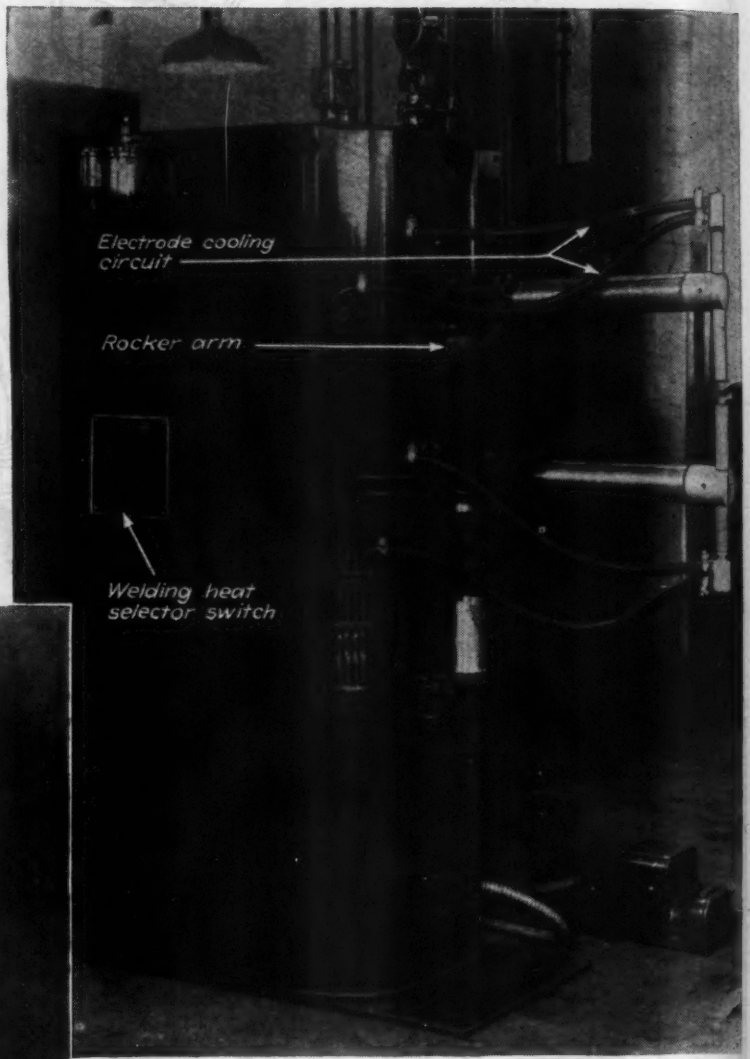
Typical hydraulic application to control several elements with a single lever. When the control lever is moved in one direction, the differentials are actuated simultaneously to open the selector valves supplying fluid to the cylinders, thus moving both elements in the same direction. Movement of the elements resets the differentials in a reverse direction until the selector valves return to neutral. Both elements are displaced equal distances in proportion to the movement of the control handle. Although both may not move at the same rate because of variations in air pressure or friction, they lock in the same angular relationships because supply of liquid under pressure does not cease until the differential connected to the particular cylinder is returned a distance equal to its displacement by the master control lever.



Electrical application of the principle. Instead of a selector valve, the differential mechanism controls a switching device as shown left. When the commutator is in position to contact the insulating segments, the motor is de-energized. When the commutator is moved to the position shown, the motor is energized for movement in one direction. When in the dotted position, direction of motor operation is reversed. The commutator arm is responsive to the movement of a suitable control member (not shown) and also by mechanical or other means is responsive to the operation of the motor.

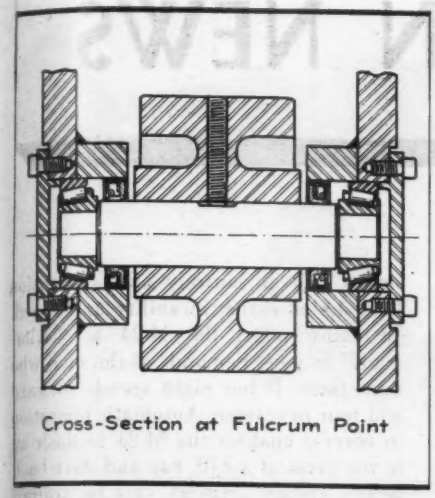
Rocker Arm Mounted on Roller Bearings

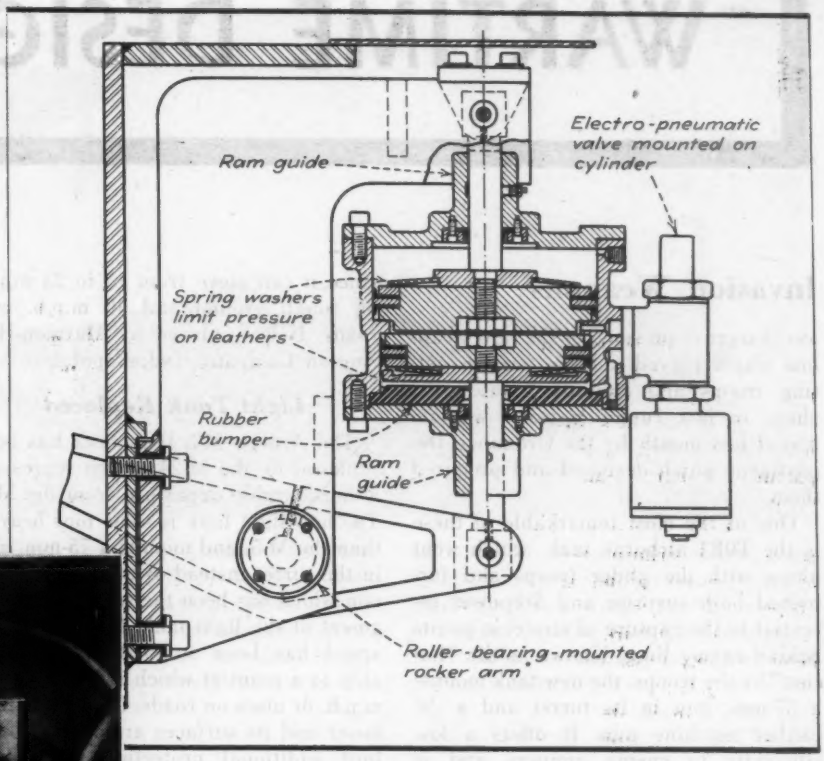
FEATURES of the new Sciaky spot-welder include anti-friction mounting of the pneumatically operated rocker arm, an all-welded frame and base and provision for magnetic or electronic current interruption. Electrode pressure is adjustable from zero to 1,000 lb. per sq. in. A pressure switch prevents machine from firing until pressure is applied to the work. This switch is adjusted to a slightly lower value than the selected welding pressure. The machine is fully automatic. When the parts being welded are in position and control switch closed, pneumatic pressure brings the upper electrode to the work. As soon as preset pressure on the work is reached, a pressure switch initiates the welding sequence. After the proper time interval, the upper electrode automatically rises.

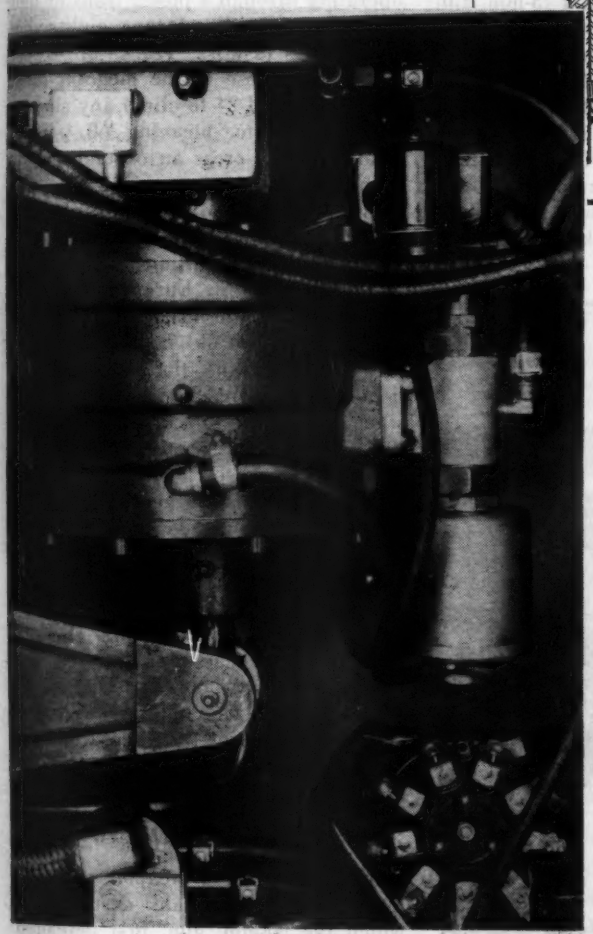


Two water circuits are used. Transformer and electrodes are cooled by one circuit, ignitron tubes by the other. Cooling coils are copper alloy. Transformer sections are electrolytic copper. Copper tubing for cooling water circulation is brazed on. Upper and lower electrode arms are hard-rolled copper, and are connected to transformer with flexible braided cable.

Electrical and electronic controls are mounted in a cabinet at the right side of the welder. The cabinet swings outward to provide accessibility to the rear wiring. Sequence panel is wired with color-coded, semi-flexible conductors. Welding sequence is initiated with shrouded-type foot switch. Inclosed in the foot switch is a foot pushbutton for use when non-automatic control of electrode retraction is desired.



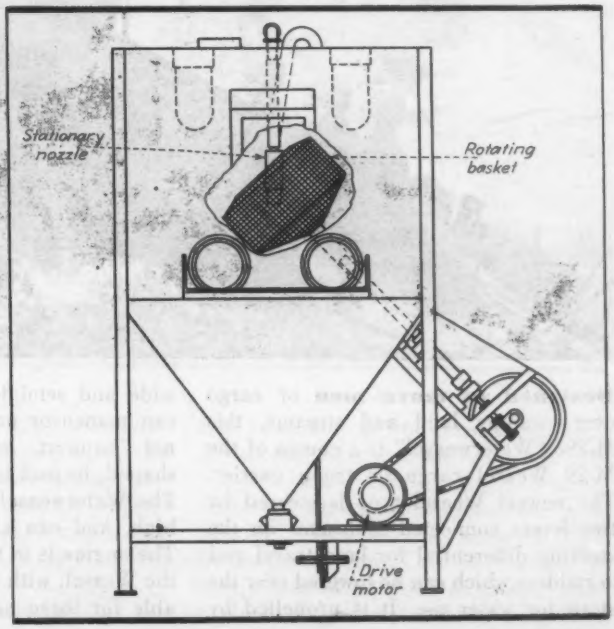




Pneumatic head and rocker arm linkage. The fulcrum point is equipped with heavy-duty roller bearings and is adjustable for wear. The pressure and rocker arm assembly is located within the welded frame and is mounted as a separate sub-frame. It is assembled and tested as a unit. A double-acting cylinder is anchored to a bracket at the top of the welder frame. The cylinder houses two pistons, one providing an operating stroke of 5/8 in., the other a retraction stroke of 5 in. Air to the cylinder is controlled through a solenoid-operated valve. Rubber bumpers cushion cylinder stroke.

Fixed Nozzle, Rotating Basket Feature New Sandblaster

MOTOR-DRIVEN ROTATING BASKET carries small parts under a sandblasting nozzle in a new design of sandblast cabinet developed by Leiman Bros. The basket is removable when large pieces are to be cleaned. Shaft in which basket is mounted is belt-driven by a standard motor. Sand is circulated from a reservoir at the bottom of the cabinet.



WARTIME DESIGN NEWS

Invasion Weapons

INFORMATION on some of the new weapons which played a large part in getting troops and equipment safely on shore in last June's invasion was released last month by the Ordnance Department which designed and procured them.

One of the most remarkable of these is the T9E1 airborne tank, which went along with the glider troops and furnished both surprise and firepower essential to the capture of strategic points behind enemy lines. Known as the "Locust" by the troops, the new tank mounts a 37-mm. gun in its turret and a .50 caliber machine gun. It offers a low silhouette to enemy gunners and is speedy enough to make a hard target since it can move from 15 to 25 m.p.h. on rough ground and 40 m.p.h. over roads. It is produced by Marmon-Herrington Company, Indianapolis.

Light Tank Replaced

The Army's M-5 light tank has been replaced by the M-24, which represents a considerable departure from the M-5. The new light tank is some tons heavier than the M-5, and mounts a 75-mm. gun in the turret instead of the 37-mm. cannon which has been the traditional armament of the light tank. In addition, its speed has been stepped up considerably to a point at which it can make 40 m.p.h. or more on roads. Its silhouette is lower and its surfaces are sloped to afford additional protection from shell hits. New, broad tracks, hydromatic drives and an entirely new suspension lend added maneuverability and speed. In many ways, the M-24 is "tailor-made" to meet demands of the men who fight them. It has eight speeds forward and four in reverse. Automatic operation in reverse enables the M-24 to dash up to the crest of a hill, fire and dart back before enemy artillery can be trained upon it. Two hydromatic transmissions operating through a power transfer unit put the two Cadillac V-type, eight-cylinder engines to work. Tracks are a foot wider than those of the medium tank, allowing the M-24 to climb any surface it can cling to, meaning 60 percent grades. It can cross an obstacle 36 in. high. Its footing, Army men say, will prove ideal in the softer terrain of South Pacific battlefields and will cope readily with the muddy conditions of spring and fall battlefields in Europe. Its operational range is 160 miles.

Instead of the old bogey suspension of the medium tank, the M-24 moves on demountable, rubber-tired suspension wheels equipped with airplane type hydraulic shock absorbers, ten wheels to a track. The wheels are placed side by side, unlike the staggered wheels on German tanks. Wheels are individually sprung and compensated, with torsion bar suspension.

Interchangeability with other units of the "Cadillac Combat Team," of which only the M-24 has thus far been announced, as well as with other equipment used by Allied nations was accomplished in designing the M-24. Right and left-hand engines are interchangeable, as are many parts of the power train.

90-MM. Tank Destroyer

Another invasion weapon just publicized is the M-36 tank destroyer, on which the 90-mm. gun, first developed as an anti-aircraft weapon, has been mounted to make the fastest major-caliber tank destroyer now fighting. It supersedes the M-10 tank destroyer which mounted a three-inch gun. Made by General Motors' Fisher Tank Division, Massey-Harris Company, and the American Locomotive Company, the M-36 has a semi-open turret with 360-deg. traverse. It is powered by a 500 hp., eight-cylinder, liquid-cooled, V-type en-

Latest Weasel Braves Swampy Land

Designed to move men or cargo over swampy land and streams, this M-29c "Waterweasel" is a cousin of the M-29 Weasel cargo or troop carrier. The newest Weasel type is steered by two levers connected to brakes on the steering differential for land travel and to rudders which can be lowered over the stern for water use. It is propelled by wide and semi-flexible full tracks and can maneuver on terrain which would not support other vehicles. Boat-shaped, its hull is longer than the M-29. The Waterweasel is 14.5 ft. long, 51 in. high, and can climb a 45-deg. grade. The engine is to the driver's right, as in the Weasel, with space in the rear available for three passengers or cargo.

Swift Kingcobra Developed for Russians

Kingcobra is the name given Bell Aircraft's latest version of the P-39 Airacobra. Shown here is the P-63 Kingcobra with a P-39 in the background. The new craft is larger, has a longer range and more speed. It is powered with the new, two-stage Allison 1,500 hp. V-12 liquid-cooled engine which affords increased efficiency at high altitudes and has a low-drag, laminar-flow wing. Armament consists of the familiar 37-mm. cannon firing through the propellor hub and four .50 caliber machine guns mounted in streamlined turrets beneath the wings. Most of the new planes will go to the Russians, who have long used the P-39 as an all-purpose fighter and ground attack ship.

American and British Rocket Equipment Differs

U.S. Army Air Forces Photo

Rockets and mountings used by the American and British Air Forces are of different design but create the same devastating effect on enemy ground targets. Compactness of the rocket-firing equipment mounted on the U. S. P-47 Thunderbolt at left is in sharp contrast to that used on the British Typhoon at right. Note the tail latch at the rear of the launching tubes on the Thunderbolt equipment. The wires on the Typhoon mounting are connected so that the discharge spark is transmitted to the propellant. The American and British rockets appear to be of about equal caliber.

gine and has a speed of 30 m.p.h. With an operational range of 150 miles. It weighs 31 tons, mounts a .50 caliber machine gun for anti-aircraft protection, can cross a 7.5 ft. trench, ford small rivers and climb grades "far beyond the ability of most military vehicles."

A new, smaller gun motor carriage is the M-18, equipped with a 76-mm. gun and capable of traveling 50 m.p.h. on roads. It weighs 20 tons and has the torsion bar type of independent suspension of the M-24 light tank. It can knock out most German tanks. It is made by Buick.

The M-20 is a new armored car for field commanders who must direct rapidly advancing motorized units. It carries two radios, one for communicating with rear headquarters, the other with advance elements. Its armored hull serves as the frame. In easy going, it uses a four-wheel drive to attain "relatively high speeds," but in rough ter-

New M-24 Light Tank Equipped With 75-mm. Gun

U.S. Army Air Forces Photo

Light tanks hit a new high in efficiency when this M-24 was put on the firing line by Cadillac and the Army Ordnance Department. It has twice the punch of the earlier M-5 light tank since it mounts a 75-mm. gun instead of the 37-mm. cannon. Suspension is entirely redesigned from earlier models which were mounted on bogey wheels.

rain it operates with a six-wheel drive. It is made by Ford's Chicago plant.

In the hand-weapons class, Ordnance has developed a jungle mortar consisting of the 60-mm. mortar tube and a combination base cap and firing mechanism. It can be carried by one man, along with a limited supply of ammunition. Fired by a trigger and lanyard device, it can operate at angles which the normal 60-mm. mortar cannot attain.

The Engineers have also revealed a new line of equipment, ranging from aluminum landing mats to mule-pack, gas-driven chain saws. The aluminum planks for landing mats weigh half as much as the traditional steel planks and can be installed much more rapidly.

Tractor Cabs Have Armor

Armored cabs for tractors and bulldozers is another Engineer development which is being installed rapidly. Cabs mount one-half inch armor plate on the sides and top to furnish protection from mines and small arms fire, and provide periscopes to allow full efficiency when the cab is totally closed.

The Tankdozer is relatively familiar by now after the record it made in clearing out the Normandy hedgerows which held infantry advances to such a limited pace. Originally developed to beat minefields, pillboxes, road blocks, wire entanglements and similar obstacles, the "dozer" blade is operated by a hydraulic jack which is powered by a pump driven off the engine. The blade and its assembly may be jettisoned within 10 seconds.

The Engineers, gas-driven chain saw has been adapted for mule pack to make it available in areas into which motor transport cannot go. It cuts hardwood up to 36 in. thick at the rate of an inch per second.

The Rochester Ordnance District is procuring a non-detectable mine consisting of an explosive charge in a ceramic case, which defeats electric detectors . . . The petroleum industry's high-octane gasoline plants are ready to switch from the production of 100-octane fuel to a new supergasoline with a "vastly improved" octane rating. The industry's war council called the "X" gas "the world's finest flying fuel" designed to "draw from the new bombers and fighters their originally intended maximums in sustained speed, short take-offs, combat radius and load-carrying capabilities."

The Navy has publicized a device for assisting carrier takeoffs through the use of a disposable jet-propulsion unit. The device is used in series of four, six or eight tubes containing jet engines, each of which delivers a thrust equivalent to 330 hp. It reduces the distance required for carrier takeoffs from 33 to 60 percent and thus allows the use of many more planes per carrier. Flying boats using the jet engines, which can be jettisoned when the plane is airborne, can get out of small lagoons they previously could not use, and can get into the air with appreciably increased loads.

105-MM. Guns on M-4 Tanks

M-4 medium tanks are now equipped with a 105-mm. howitzer, the biggest gun ever installed in a medium tank, making it "the master of any German tank now in the field," the Army reports . . . The Germans are using a new "Pantiger" tank, an offshoot of its 60-ton Tiger and a later model "Panther" 45-ton tank. A Pantiger, weighing 65 tons and mounting 6-in. armor plate, was captured by the British in Normandy after a mechanical breakdown. It was 23 ft. long, more than 11 ft. wide and had an extra wheel on each side. . . . Glider-towing planes are using a new cable cutter mounted on the airplane for emergency use. An explosive charge is located outside the plane, detonated by an electric spark . . . On the sea, the Allies are using a new electric mine which defies normal mine-sweeping practice. It is detonated by sound and has rendered sea-borne traffic between Germany and Sweden almost non-existent, a Swedish news agency said.

Only Might Can Guarantee Peace

AS THE END of the German war approaches, the insidious propaganda of pacifists and isolationists is again being directed at Americans via radio, newspapers and magazines.

Again they are unfolding their shopworn arguments of 1919, urging that the United States set the example for all the world to follow by disarming completely and refraining from any activities that contribute to military preparedness. These unrealistic thinkers argue that leadership devoted to their principles will guarantee eternal peace throughout the world.

In the light of the world-shaking events of the past decade, it is inconceivable how men of intelligence can continue to chant such asinine arguments.

If the rantings of the pacifists had been accepted and acted upon prior to December 7, 1941, the Japanese would have been spared from staging the treacherous sneak attack on Pearl Harbor. With no fleet or military equipment to counteract them, the Japs would merely have taken over not only the Philippines but also Hawaii and our West Coast without firing a shot. Thus the pacifists would have won their point that total unpreparedness is a positive preventive for war.

We must never forget that man is a fighting animal. There will always be some persons with distorted, fanatical minds to think up real or fancied grievances. By grandiose promises they gather followers and resort to force to gain their ends. Such leaders may be city gangsters or international hoodlums. Only force can control them. Gangsters are checked by armed policemen. International hoodlums can be forced to hold the peace only by powerfully armed nations; they do not fear nations that are weak militaristically.

When this war ends we must continue to maintain a reasonably strong Army and Navy, and we must keep in continual operation a comprehensive program for the development of ever-superior weapons, motorized armor, warplanes and fighting ships. Never again should this nation permit itself to be in the unprepared condition with which we entered this war.

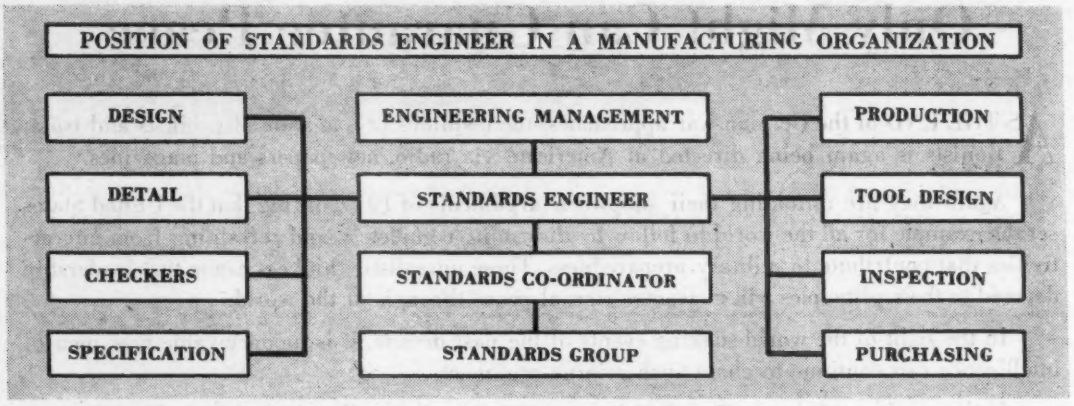
We, as a nation, must adopt a permanent policy of engineering preparedness. Ever-improved equipments and pilot-plant models that possess the greatest military values science and engineering can devise must always be ready for mass production. The cost of such preparedness is insignificant when measured against the terrible price paid by the American boys on Guadalcanal. Thousands were killed and maimed because they did not have the stuff with which to fight.

G. F. Zodenkolt

Engineering Standards Systems Reduce Design Costs

ARNOLD REUSS
Engineering Department, Koehring Company

Presenting a plan for inaugurating and organizing a system that develops a sound and uniform approach to many design and production problems, with departmental and personnel considerations that make desirable the adoption of an engineering standards system. Method for indexing and compiling standards books is described in detail.



THE problem of an inadequate supply of experienced technical help to fit into various industries will confront the nation for several years to come. Government demand for engineers will be felt for some time by industry after the war is over. The new crop of young engineers, as well as the older ones that will be released by the government, cannot be trained overnight. Simplifying technical work as much as possible, and spreading the available skilled help as thin as possible, will in some degree relieve these conditions.

A well conceived and properly used engineering standards system will go a long way in bridging this gap. But standards must be based on specific needs and demands. They must concisely record all possible known factors that are involved in specific design problems, detail production, purchasing, and costs. They must be prepared in a manner for easy reference and interpretation by the entire technical staff.

Many organizations have learned that standards reduce engineering and production costs, also that standards help to provide the means to increase worker productivity by providing accepted methods to design approach.

The value of an engineering standards system is directly proportional to the attention given each and every detail, and its completeness and comprehensiveness. Unless it is diligently and systematically kept up-to-date and energetically employed, it will be of limited value.

Many engineering departments collect a miscellaneous assortment of engineering and shop data in some form or other. Likewise, many engineers build up their own design manuals and records which they jealously guard for their own personal use. They are reluctant to share their specialized knowledge and skill with others. Likewise the rank and file of the staff are only partially equipped with knowledge of their employer's past problems and company policy. This fact makes it necessary for vigilant supervision by a few key men who have this specialized training.

An engineering standards system must be practical and vital. It must have the complete support of the engineering and manufacturing departments. Putting this system in operation and keeping it functioning smoothly is not an easy job.

Individual temperaments of those using or involved by the use of this system must be given careful consideration. Existing practices throughout the organization must likewise receive proper attention. Each organization and type of business has problems peculiar unto itself.

Many small and medium-sized industrial concerns are conscious of the need for some kind of standards system but treat the idea as a stepchild. It is not considered productive work, when in reality it offers a means to obtain higher productivity and lower costs. A properly conceived engineering standards system provides many benefits, including:

1. Means of increasing the draftsman's productivity by furnishing him with definite information based on company standard practices. Considerable tabular and illustrative information is available for a wide range of work.
2. Supervisory work is materially reduced since ample data is available to all engineering staff members.
3. Aid to the checkers. Recorded data provides a source to obtain uniform information.
4. Guide for a uniform method of illustration of details for easy interpretation by the shop.
5. Proved means of approach to the many technical problems for designers.
6. Simple and tactful means for educating new employees to the engineer-

CHART A—ENGINEERING STANDARDS BOOK NO. I, DRAWING STANDARDS

Subject	Section
Drawing Room Policy and Practice Department policy, records, time sheets, numbering and filing, engineering change notices, material listing, model numbers.	A
Detailing Practice Abbreviations, nomenclature, dimensioning practice, welding practice, surface finish standards, fits and tolerances, keyways, fitted parts.	B
Standard Details Grease retaining grooves, blind tapped holes, shaft centers, cast gear tooth forms, gear backlash, gear centers, chordal measurements of gear teeth, cast sprocket teeth, cast countersinks, cable grooves, wrench clearances, drills and taps, two-hole pin proportions, bronze bushing details, worm thrust directions, bolt and nut standards, friction lining fastenings, babbitting practice, strength of welds, tolerances and fits.	C
Typical Drawing Details Compression spring, tension spring, shafting, bevel gear, spur gear, standard parts, assemblies, structural details, purchased parts, remachined parts, clutch and brake band details.	D
Shop Practices This section is devoted to processing procedure and standard practices. Frequently designs and details are influenced by shop methods and equipment. Sufficient information should be included as experience dictates.	E
Tools and Equipment Drills, taps, reamers, gear cutters, broaches, punches. Maximum sized parts the larger machine tools can handle on lathes, boring mills, boring bars, gear cutters, brakes, shears.	F
Materials in Stock Shafting, tubing, plates, sheets, rounds, flats, channels, I beams, angles, bolts, cotters, pipe.	G
Sections H, I, J and K will complete Book No. I. Subject matter for these sections will suggest themselves according to needs.	

CHART B—ENGINEERING STANDARDS BOOK NO. II, DESIGN STANDARDS

Subject	Section
Mechanics and Dynamics of Design This section would start off with a foreword on design as it affects company policy. It includes some of the most generally used fundamental engineering formulas. The purpose of the Book No. II is to list major principles, indicate the solutions of the conditions they set up and show several examples in the field of machinery design. In short this entire section is to provide a proved or accepted means of approach to the many technical problems involved in the design of the company's product.	L
Engineering Materials Complete tabular information on materials used by company of carbon and alloy shapes and castings with their respective chemical and physical properties. Heat-treating data, commercial tolerances.	M
Shafting Design Symbols, service factors for various units, order of steps in design, forces acting on shafting, moment diagrams, allowable deflections, maximum allowable stresses, bearing selection, bearing efficiency factors, strength of keys and splines, stress concentration factors, examples.	N
Gear Design Symbols, typical gear train layouts, formulas, order of steps in design, tables, gear proportions, castings and weldments, examples.	O
Clutch and Brake Design Symbols, classification of different types, table of recommended practices, basic formulas, order of steps in design, derivation of trial formulas, diametral expansion caused by heat, toggle versus sleeve travel, *DE* and *LE* ratio graph, lining values and types, fastenings, cooling fins, examples of computation.	P
Spring Design Symbols, typical drawings, properties of spring steels, approximate loads for various *D* and *d* ratios, tables, order of calculations and examples, spring selection graphs.	R
Boom Design—Crane and Shovel Illustrations of attachments, order of steps in design, forces acting on booms, forces acting on dipper sticks, examples.	S
A-Frame Design Forces acting on A-frames, high and low types, examples.	T
Swing Moment Determinations Forces involved, examples.	U
Tipping Capacities Forces involved for crawler and rubber-tired types, examples.	V
Miscellaneous Forces exerted by roller loads, design of cable drums, power plant data.	W
Cost Data	Z

ing department in accordance with company standard practices.

7. Means for preliminary cost estimating in the designing department.

8. Means of supplying the engineering department with information on shop practice and equipment.

Many concerns year after year bring out new designs, build up huge capital investments in materials, tools, patterns, fixtures and obsolete items, but give only partial consideration to past experiences and problems. Credit, of course, must be given for the many advances made in the past in the field of machinery design, but the evidence presented each year indicates that there is room for improvement in the repetition of errors and high initial costs of design and detail.

A typical example will make clear the

CHART C—BOOK III, STANDARD PARTS

Balls (lever)	Handles (door)	Sheaves
Bearing boxes	Keys	Shims
Bell cranks	Levers	Sockets (wedge)
Bolts	Lock or keeper plate	Sprockets, studs
Bushings	Pads (rubber)	Snap rings
Clevises, yoke ends	Pins	Spacers, pipe or tubing
Clamps (pipe)	Pipe clamps	Springs
Collars	Plugs, graphite, asbestos	Studs
Dowels	Rods	Tubes
Fillers (plate)	Rollers	Washers (shaft ends, spacers)
Gaskets	Rod ends	Wedges
Gears	Rivets (rivet pins)	Yoke ends, clevises
Grips for doors, levers	Screws	Yokes (clutch shifter)

CHART D—SHAFTING DESIGN—SECTION N

	Sheet No.
Typical shafting	1
References	2
Symbols	3
Order of steps in design	4
Shaft layout	5
Forces acting on shafts	6; 6A; 6B; 6C; 6C-1; 6D
Bending moments and moment diagrams	7; 7A
Service factors	8
Maximum stress and diameter	9
Linear deflection	10; 10A; 10A-1; 10B
Summary sheet for record	11
Selection charts (shaft diameter)	12; 12A; 12A-1; 12B
Example	13; 13A; 13B; 13C
Bearing selection—all types	14; 14A-1; 14A-2
Efficiency factors for bearings—anti-friction	15
Keys and keyways	16; 16A; 16A-1; 16B
Shrinkage fits	17; 17A; 17B; 17C
Factors contributing to stress concentrations	18; 18A; 18B; 18C; 18D
Torsion moments and torsional deflections of solid and hollow shafting	19–19A
Splines—SAE std. housing dimensions	20
Splines—torque capacities	21

inauguration and operation of an engineering standards system. A system will be selected suitable for a manufacturer of medium and heavy construction equipment.

Essential Qualifications

The selection of an engineer to head the standards group is the first problem. The man chosen should have a good general engineering background with experience in production, materials, purchasing and cost problems. He must be able to win the support of engineering and non-engineering groups. In his associations with the design departments he must be constantly alert to the possibilities of the proper standards to adopt. He must be able to instill in those with whom he works the possibility of standards and make them conscious of the over-all benefits.

After the standards engineer has been selected, he will have to do considerable preparatory work. Consultation with the designing staff members concerning their views and opinions is important. Those in charge of the departments indicated in the organization chart on page 670 should be consulted concerning their views on this project. During the course of these conferences, notes can be made and later correlated so that some sort of start can be made. As work gets underway, many ideas will suggest themselves for improvement.

The engineering standards department should be under the control of the chief engineer or engineering management. Close relations with design, production, tool and purchasing departments should be constantly maintained.

After the standards engineer has made his preliminary investigations, his first step would probably prompt him to set up some subject headings to work on such as:

1. Company policy and department standard practices.
2. Drafting practices.
3. Shop practices.
4. Design practices.
5. Standard parts.

These headings would then be broken down into many sub-headings.

The number of standards books that will be required to facilitate handling and easy reference might well be considered next. Typical subject headings for three engineering standards books are listed in Charts *B*, *C*, and *D*, with sub-headings.

Book No. I—Would cover subjects under headings, 1, 2 and 3.

Book No. II—Would cover subjects under heading 4.

Book No. III—Would cover subjects under heading 5.

A brief index for each set of books should next be set up. This will provide an outline of the various subjects that will require consideration. Indexing and numbering of sheets must be done carefully. They must be arranged so that changes and additions can be inserted in any portion of the book without disturbing the sequence of any subject. Loose leaf books are the obvious choice. These will permit additions of new material or removal of material.

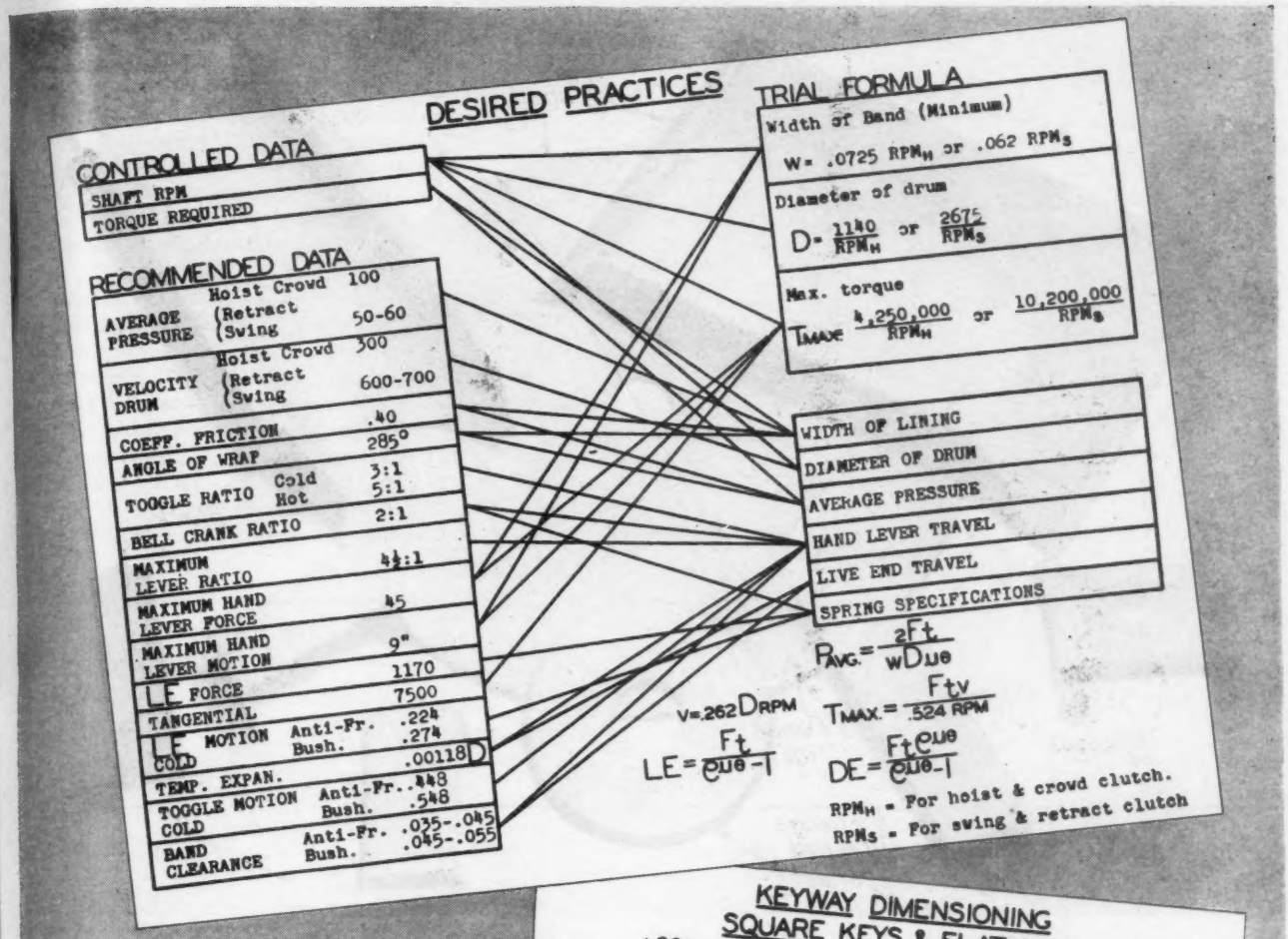
The method of numbering each sheet is explained by Chart *E* which is the chapter index on Shafting Design. This subject is covered by Section *N*. This letter *N* will appear on all sheets covered by this chapter in the lower right-hand block. Each item listed in the index is covered by a particular number. Referring to the item "Forces acting on shafts" the several sheets are numbered 6, 6A1, 6B1, 6C-1, 6D. The insertion of sheet 6C-1 is to maintain continuity of the subject matter in the event sheet 6D has been in existence. Any number of new sheets can thus be inserted without disturbing the continuity of the subject.

Sample sheets taken from a typical engineering standards book are reproduced in Figs. 1 and 2. The sheet shown in Fig. 1 is an excellent illustration of how interrelated standard design formulas can be set up in visual diagrammatic form. Sheet shown in Fig. 2 gives formulas and an example of their use.

Standard Parts List

A list of so-called standard parts which are commonly used would be entered in Book III. Practically every engineering department has some sort of record of these items. The methods for recording vary. Some companies record these items on regular drawings and tabulate those that lend themselves to this method. The loose leaf book form offers the most convenient method and is the most easily used.

All standard items are listed in a permanent standards list, according to general dimensions, under the supervision of the file clerk. Before detailing a new standard item, the standard list must



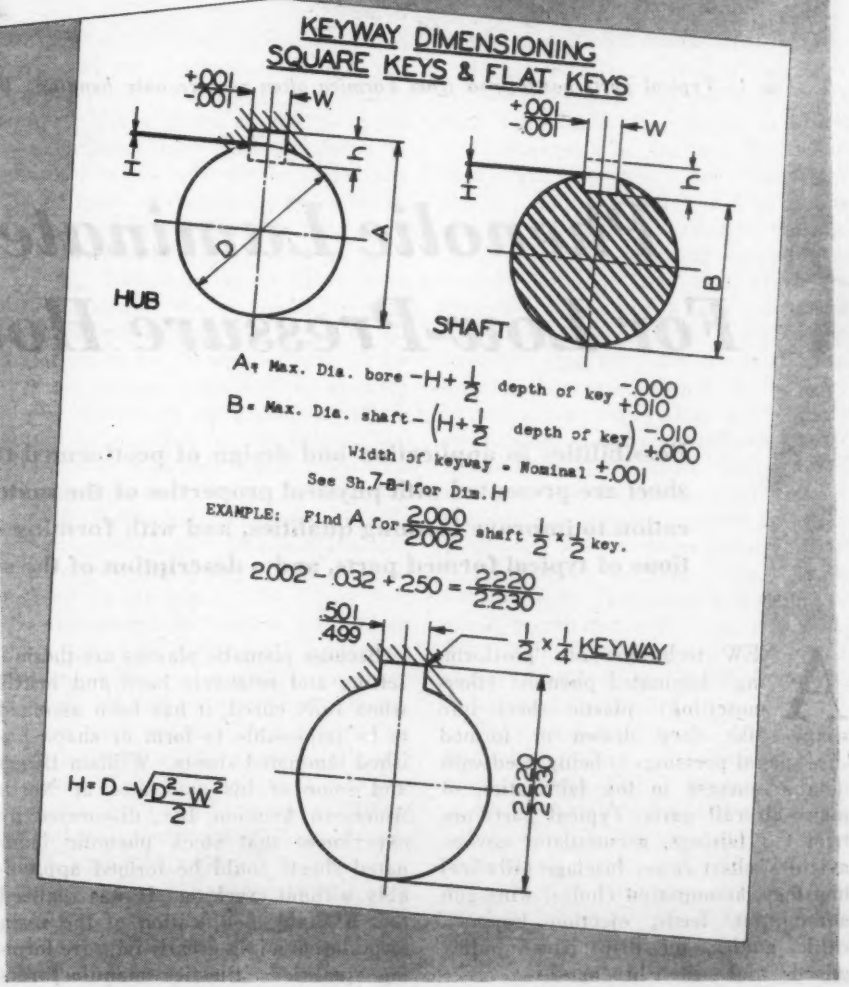

KEYWAY DIMENSIONING
SQUARE KEYS & FLAT KEYS
+.001 -.001
W
C
I
D
A
HUB
SHAFT
B
A = Max. Dia. bore - H + ½ depth of key -.000 +.010
B = Max. Dia. shaft - (H + ½ depth of key) -.010 +.000
Width of keyway = Nominal ±.001
See Sh. 7-8-1 for Dim. H
EXAMPLE: Find A for 2000/2002 shaft ½ x ½ key.
2002 - .032 + .250 = 2220/2230
.501
.499
½ x ¼ KEYWAY
H = D - √(D² - W²)/2

Fig. 1 (Above)—Sample sheet from engineering standards book illustrating scheme for presenting interrelated design data. Fig. 2 (Right)—Sample sheet listing standard method for dimensioning keyways in shafting and wheels.

be checked to see if a suitable part is already in production. If suitable parts are not in production proceed as follows:

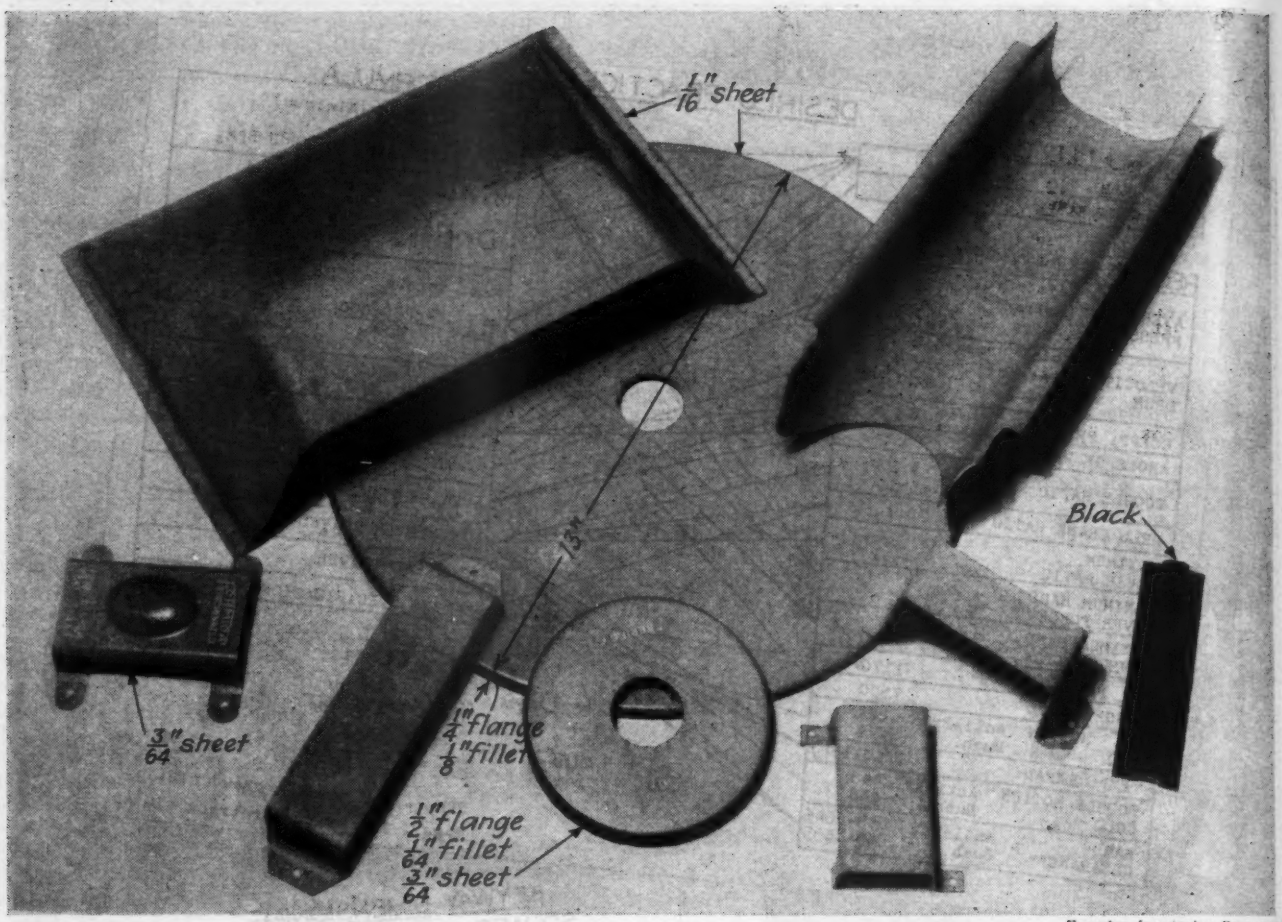
1. Make new detail drawing.

(a) Drawing must be free of all reference to specific machines, drawings and assemblies.

(b) "Amount required" must be omitted from the title block.

(c) Part is to be entered in standard book by file clerk immediately after number is issued to prevent duplication of that part.

Only a few of the high spots concerning the value of a standards system have been described, along with an outline of some of the mechanics for inaugurating a workable system. The intelligent use of a good standards system will help to develop a sound and uniform approach to many design and production problems.



Formica Insulation Company

Fig. 1—Typical parts postformed from Formica often require only bending. Wide circular flanges are more difficult.

Phenolic Laminated Sheet For Low-Pressure Hot-Forming

Possibilities in application and design of postformed thermosetting laminated sheet are presented with physical properties of the material after slight modification to improve forming qualities, and with forming characteristics, illustrations of typical formed parts, and a description of the simple forming method.

A NEW technique of "postforming" laminated phenolic (thermosetting) plastic sheet into shapes like deep drawn or formed sheet-metal pressings is being used with notable success in the fabrication of many aircraft parts. Typical parts are trim tab fairings, accumulator covers, aviators' chart cases, fuselage tailwheel housings, ammunition chutes, wing-gun ammunition feeds, ejection hoppers, cable guides, oil drip pans, pulley guards, and switch brackets.

Because phenolic plastics are thermosetting and relatively hard and brittle when fully cured, it has been assumed to be impossible to form or shape finished laminated sheets. William Beach and some of his associates at North American Aviation, Inc., discovered by experiment that stock phenolic laminated sheets could be formed appreciably without cracking. It was realized that a slight modification of the resin formulation might greatly improve forming qualities. Plastics manufacturers soon achieved the desired goal with but slight effect upon the other desired properties of the material. Thus was developed technique and material for what is now known as postforming of phenolic resin sheets. The process involves heat and low pressures.

Formability of such laminated sheet is shown by the accompanying illustrations. Since this method of fabrication is a wartime development, peacetime posibilities are practically untouched. One application to mock-ups for postwar

refrigerators has proved to be highly successful. Doors, door frames, and other parts are satisfactory for refrigerators that are put in homes for test. Postformed laminated sheets can be used for instrument cases, guards, and many other parts similar to those now made of this material for aircraft. Other applications will include those that require high insulating qualities.

Size of postformed parts ranges up to as large as the sheet can be made. A reinforced panel formed in a 4 by 8 ft. sheet has been produced. It has been estimated that 90 percent of postformed parts are now made of $\frac{1}{16}$-in. and $\frac{3}{32}$-in. sheet but thicknesses up to ½ in. have been postformed. On some of the small parts, such as an earphone part, extremely close dimensional tolerances can be maintained. Thermal expansion

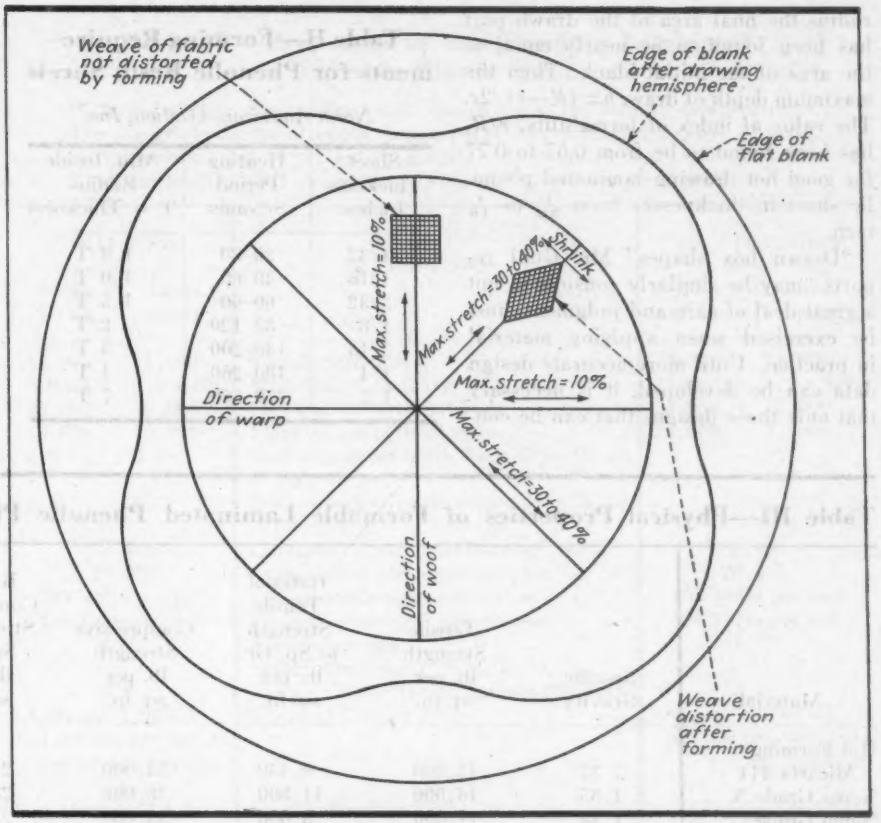

Weave of fabric not distorted by forming
Edge of blank after drawing hemisphere
Edge of flat blank
Max. stretch=10%
Max. stretch=30 to 40% Shrink
Max. stretch=10%
Direction of warp
Max. stretch=30 to 40%
Direction of woof
Weave distortion after forming

Fig. 3—Approximate effects produced in the fabric of a circular blank of laminated sheet when forming a spherical cup.

Table I—Drawing Limitations for Phenolic Resin Sheets

North American Aviation, Inc.

Sheet Thickness Inches	Max. Depth of Draw Inches	Min. Radius of Draw Inches
Up to 1/16 incl.	1	1½
1/16 to 1/8 incl	1/2	5
1/8 to 1/4 incl.	1/4	10
1/4 to 1/2 incl.	1/4	20

Panelyte Div., St. Regis Paper Co.

Fig. 2—Cup formed from an octagonal blank shows distortion of fabric.

characteristics and the effects of humidity are more noticeable on large parts and might amount to several thousandths in 30 inches.

Production advantages of postformed thermosetting laminated sheets include simplicity and low cost of dies and equipment, ease of production, flexibility of design with dies of wood or other material that is relatively easy to work, and the convenience of stocking sheet material, which can be readily converted into parts at the point of manufacture. Many parts that formerly could be made only of thermoplastics can be made of thermosetting material.

Cotton fabric laminants are commonly used in laminated sheet for postforming. Although cotton fibers have little elasticity, the woven fabric can be stretched appreciably by virtue of the crimp in the weave and twist in the threads. Added to these is the skewing of the warp and woof threads, which permits elongation on the bias in the direction of pull and causes it to draw together perpendicular to the direction of pull. These characteristics ordinarily permit approximately 10 percent stretch lengthwise and crosswise, and 30 to 40 percent on the bias.

Development of fabrics that permit more stretch or distortion is underway. One manufacturer of textiles predicted a fabric capable of 300 percent stretch. Details were not disclosed except that such material would be equally strong before and after stretching, a fact that indicates it is not a knit weave. Fabrics of materials such as wool, glass, Nylon, linen, and others have also been considered. Crepe paper laminants are practical for many parts but lack strength and forming qualities of fabrics.

No universally applicable rules for the design of postformed parts have yet been formulated. The depth to which $\frac{1}{16}$-in. sheet can be drawn is illustrated by a round cup with a rim diameter of 3½ in., spherical bottom of 3 in. radius and 1½ in. deep. Behavior of the material during the drawing operation is entirely different from that which occurs in drawing sheet metal. In sheet metal, the material either upsets or is stretched elastically and plastically. In drawing laminated sheets, the redistribution of the material is by displacement rather than by appreciable elastic deformation of the fibers. Distortion of the weave of the fabric, stretching on the bias and drawing together on a perpendicular axis, plays an important part in the forming operation. Fig. 3 shows roughly what takes place in forming the above mentioned cup from a circular disk. Table I gives the drawing requirements specified by North American Aviation, Incorporated.

The degree of spherical forming can be predetermined, according to H. C. Guhl, Westinghouse Micarta department, by calculating an index of formability, which is the ratio of cup radius r to blank radius, R. The numerical value of r/R determines the maximum depth to which a blank of radius R can be drawn. For cylindrical flat bottom cup drawn parts with small corner

radius the final area of the drawn part has been found to be nearly equal to the area of the initial blank. Then the maximum depth of draw, $h=(R-r)/2r$. The value of index of formability, r/R, has been found to be from 0.67 to 0.77 for good hot drawing laminated phenolic sheet in thicknesses from $\frac{1}{32}$ to $\frac{1}{16}$ inch.

"Drawn box shapes" Mr. Guhl reports "may be similarly considered but a great deal of care and judgment must be exercised when applying material in practice. Until more accurate design data can be developed, it is necessary that only those designs that can be considered 'safe' be adapted to deep drawn box shapes."

Table II—Forming Requirements for Phenolic Resin Sheets

North American Aviation, Inc.

Sheet Thickness Inches	Heating Period Seconds	Min. Inside Radius T = Thickness
1/32	20–30	1.0 T
1/16	40–60	1.0 T
3/32	60–90	1.5 T
1/8	80–120	2 T
3/16	130–200	3 T
1/4	180–260	4 T
1/2	370–560	7 T

Bending requirements of "formable" resin-impregnated laminated sheet, as specified by North American Aviation, Inc., are given in Table II. Still smaller radii have been obtained in 90-deg. bends.

Physical properties of a representative material used for postforming are compared with properties of other grades of phenolic laminated plastics and of other lightweight materials used in aircraft in Table III. Table IV compares physical properties with and across grain for natural tan and dark

Table III—Physical Properties of Formable Laminated Phenolic Plastic Sheet, Woods and Metals

Material	Specific Gravity	Tensile Strength lb. per sq. in.	Ratio of Tensile Strength to Sp. Gr. lb. per sq. in.	Compressive Strength lb. per sq. in.	Ratio of Compressive Strength to Sp. Gr. lb. per sq. in.	Modulus of Elasticity in Tension lb. per sq. in.	Modulus of Elasticity in Compression lb. per sq. in.
Hot Forming Micarta 444	1.37	13,000	9,450	33,000	24,100	0.9×10^6	0.55×10^6
Nema Grade X	1.35	16,000	11,800	38,000	28,100	1.7×10^6	0.83×10^6
Nema Grade C	1.38	11,000	8,000	35,000	25,400	1.05×10^6	0.56×10^6
Aircraft Spruce (Douglas fir)	0.43	10,000	23,300	5,000	11,600	1.3×10^6	1.3×10^6
Birch Plywood	0.80	13,100	16,400	5,700	7,100	1.4×10^6	1.3×10^6
Stainless Steel (18–8)	7.85	185,000	23,600	150,000*	19,100	30×10^6	30×10^6
Aluminum Alloy (24-St.)	2.80	62,000	22,100	40,000*	14,300	10.4×10^6	10.4×10^6
Magnesium Alloy (Am-585)	1.81	46,000	25,400	35,000†	19,300	6.5×10^6	6.5×10^6

* Yield point in compression. † Yield point in tension. Yield point in compression is substantially equal to yield point in tension in wrought alloys.

(Taylor Fibre Company)

Fig. 4—Hopper assembly as designed in postformed laminated plastic and in sheet stainless steel.

green material. Fig. 5 illustrates the effect of temperature on ultimate tensile strength of postforming sheet as compared with a standard grade laminated sheet unmodified for forming. Change in tensile strength with temperature is considerably greater in the modified material. The effect is similar on impact strength.

Although the strength of postformed laminated plastic parts is low in many respects as compared to sheet metals, they have other characteristics in service that often more than compensate for this limitation. Often the heat-insulating as well as electrical-insulating property is an important advantage. High compressive strength as compared with birch plywood is advantageous though tensile strength is approximately the same. Specific gravity is half that of aluminum. For a given weight, structural stiffness is considerably greater than steel.

In some applications frictional properties or abrasion resistance have been better than metal. Resilience, elasticity and resistance to denting are important considerations in weighing advantages with sheet metal. Like the more familiar flat laminated sheet material it withstands and absorbs vibrations and reduces noise. Corrosion resistance is also practically unchanged by modification for forming.

Color is preferably natural tan. Green and black sheet is available but since phenolic resin plastics are difficult to color uniformly and hold a given shade, colors are still limited. Special cellulose-type lacquers have been developed, however, which give a wider choice of color.

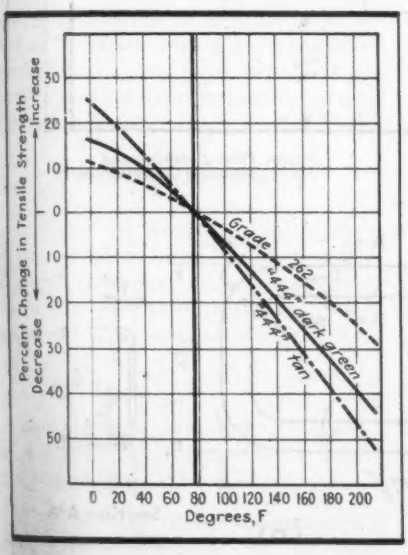


Fig. 5—Thermal effects on ultimate tensile strength of postforming grades of Micarta compared with standard grade.

Table IV—Properties of Hot Forming Laminated Phenolic Plastic Sheet

Natural tan sheet has greater tensile elongation at the forming temperature. The tan grade has an ultimate elongation of 10 percent lengthwise, 12 percent crosswise, and 40 percent diagonally. Dark green sheet will elongate 9 percent lengthwise, 9 percent crosswise, and 25 percent diagonally.

"444" Tan		Properties	"444" Dark Green	
With Grain	Gross Grain		With Grain	Cross Grain
13,000	11,000	Tensile Strength	13,000	11,000
0.9×10^6	0.9×10^6	Modulus of elasticity	1.1×10^6	1.1×10^6
19,000	16,000	Flexural strength flatwise	24,000	18,000
19,000	16,000	Flexural strength edgewise	24,000	18,000
2.9	2.3	Izod impact strength flatwise ft. lb. per 1 in. width	6.0	5.0
1.3	0.7	Izod impact strength edgewise ft. lb. per 1 in. width	3.0	2.0
33,000		Compressive strength flatwise	37,000	
16,000		Compressive strength edgewise	20,000	
240 Volts per mil		Dielectric strength short time	200 Volts per mil	
130 Volts per mil		Dielectric strength step by step	100 Volts per mil	
1.37		Specific gravity	1.39	
6.0		Water Absorption (A. S. T. M.) 3 x 1 x 1/16 (Weight gain in 24 hours.)	4.5	
(Approx.) 0.00061 Cal per sec. per deg. C. per sq. cm. per cm.		Thermal Conductivity	(Approx.) 0.00061 Cal. per sec. per deg. C. per sq. cm. per cm.	
(Approx.) 0.4		Specific Heat	(Approx.) 0.4	
(Approx.) 17×10^{-6} per deg. F.		Thermal Coefficient of Expansion	(Approx.) 17×10^{-6} per deg. F.	

Note: Properties' data are averages based on tests made by A. S. T. M. methods. Samples were tested in the "as received" condition at approximately 70 deg. F. temperature.

No baking enamels can be used because the material will not stand the high temperatures required.

So little pressure is required in bending and forming phenolic laminated plastic sheet that dies can be made of well seasoned hard wood. As many as 3,000 parts have been made with such dies without damaging them. Besides this inexpensive material, compressed impregnated plywood, cement, laminated phenolic plastic, metal, and other materials have been used for dies. Metal dies are used when the shape is complex or the number of parts is large. Its greater heat conductivity is sometimes objectionable but can be circumvented.

In preparation for the forming operation the surfaces of the blank are heated to just below the blistering point. One producer recommends timing 3 to 5 seconds less than that required to blister, as determined by trial. Others feel safer with a spread of 15 to 20 seconds. Timing depends somewhat on the temperature of the heat source, method of heating, and thickness of sheet. Temperatures and timing are fixed to make the sheet limp and pliable for forming. A slower heat would obviously have to be used with a thick material than with a thin sheet. Temperature of forming is 250 to 300 deg. Fahrenheit.

Any of several heating methods can be used: Parallel hot plates, oil or metal baths, hot-air ovens, infra-red radiant heat, and dielectric heating. When using a hot-air oven heated to 450 deg. F., a $\frac{1}{16}$-in. blank of forming stock may be ready to form in 45 sec. A blank of $\frac{3}{8}$-in. material requires approximately 5 min. in the oven.

The pressure required to form the new laminated phenolic plastic sheet depends upon the size, type of operation and thickness of the sheet and will vary from a few pounds for a simple bending operation to several hundred pounds per square inch when drawing thick sheets. Hand arbor presses, hand bending presses, air arbor presses, and hydraulic presses have been used successfully. The formed part is retained in the mold until cool enough to hold its shape. This period can be shortened by forced cooling with air or water but may have to be lengthened in some instances when metal dies are used.

Clearance between sides of the pressing block and sides of the forming block

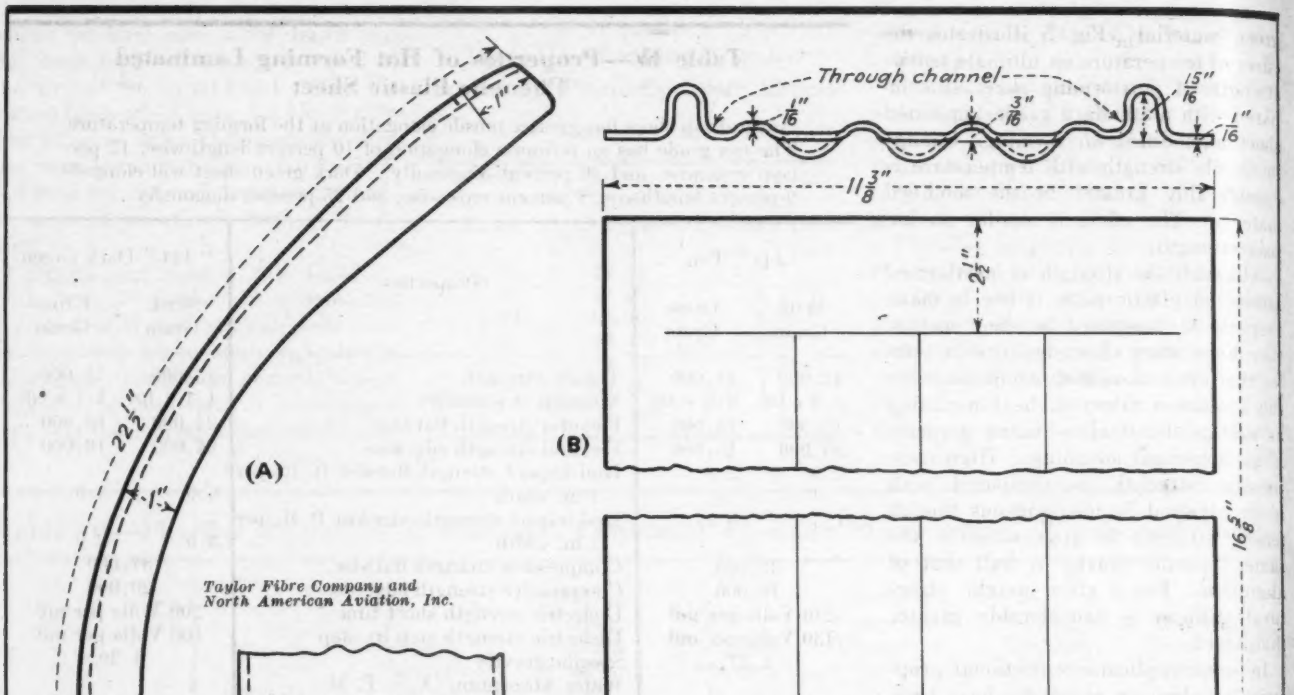


Fig. 6—(A) Flanged guard formed in ⅛-in. laminated sheet. (B) Drainboard-like panel made of 1/16 in. laminated plastic. (C) Approximate cross-section of an ammunition chute nearly 9 ft. long made from flat sheet 12 in. wide. Chute is twisted 30 to 60 deg. at assembly. (D) Flanged frame with 9/16-in. stretch flange proved more difficult to form than anticipated. Advantage can be taken of bias stretching at the inside corners with a large radius by properly shaping the blank.

is recommended by one producer to be 0.010 in. greater than maximum thickness of the sheet.

Assembly Methods

Commonest methods of assembling formed laminated plastic members with other members are by rivets and cements. Two manufacturers have found a resorcinal base cement or resorcinal resin cement to be most satisfactory because it requires no pressure and little or no heat. Products made by Pennsylvania Coal Products Company and Casein Corp. of America are satisfactory cements of this type. Thermosetting adhesives such as phenolic and furfural types, and Cycle-Weld are also suitable materials. Sanding is the only surface preparation required.

Other fabrication methods such as machining, buffing, sawing, drilling, and punching are accomplished the same as on standard laminated phenolic material. Tapping and threading are also possible but not commonly used on thin sheet.

Acknowledgements for providing the data in this article are accorded to engineers of Formica Insulation Company, 4613 Spring Grove Ave., Cincinnati, Ohio; Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.; Panelyte Division, St. Regis Paper Company, Trenton, N. J.; and Taylor Fibre Company, Norristown, Pa.

Design Engineers Want More Information in Catalogs

E. A. PINGER
Standards Engineer, Consolidated Vultee Aircraft Corporation

Criticisms of present catalog practice and recommendations contained in a study made by the National Aircraft Standards Committee are given in this article. Advantages of good catalog files containing specific technical information, proper indexing and minimum requirements are also discussed.

THROUGHOUT industry today there is a need for improvement in the cataloging of equipment and hardware articles. Satisfaction of this need would be advantageous to vendors and purchasers of these items. The results of a study toward this end by member companies of the National Aircraft Standards Committee might well be considered as an open letter intended to assist and guide companies interested in compiling new catalogs or in improving their current cataloging methods.

Contributing Causes

Although the need for improvement in this phase of any economic system of supply and demand is always present, it has been accentuated by a number of causes, among which are:

1. Complications brought about by the large quantity of new products which have been placed on the market as a result of the tremendous strides made during the last few years.

2. Introduction of new manufacturing firms, or the branching out of established manufacturers into the production of items entirely unrelated to their regular products.

3. Information required by the aeronautical industry is of relatively small importance in other types of manufacturing. Typical of this information are such items as envelope size, weight and temperature operating range of products. Each of these is vitally important to the airplane designer who must usually fit the equipment into a limited space, and must, at the same time, carefully limit weight and provide assurance that all equipment will operate in extreme temperatures of from —70 deg. F. to 130 deg. F. range.

4. The large quantity of commercial parts which are employed in the construction of modern aircraft. These figures vary from approximately 2,700 in the case of small basic trainer designs in the 3,500-lb. class, to some 53,000 parts in a 28-ton Liberator bomber, exclusive of government - furnished equipment and quantity-purchased items such as bolts, nuts and rivets. In ordering, stocking and handling such large quantities of parts, it is imperative that each part be correctly and concisely identified by number as well as by name to permit proper production control. It is surprising to note how many products are not properly identified.

Advantages of Good Catalogs

The purposes of maintaining in the engineering department a good file of parts catalogs are to: Quickly determine possible standard parts that might be used and thereby reduce the number of custom-built parts; provide sufficient information for the design application, ordering and proper identification of the parts.

On the other hand, the advantages to be gained from a file of well-prepared catalogs by the vendors as well as the purchasers of such products are quite extensive. A well planned, technically useful and carefully indexed catalog is an invaluable salesman. It should be kept in mind that a technically trained person determines what products are to be used on a design. Within certain limits, he knows exactly what he wants and his principal problem is to find it. The solution of this problem would be greatly simplified if the designer has informative catalogs of company products on his bookshelf, or at least not farther removed than the technical library which is usually maintained in all large manufacturing plants. Therein lies one of the principal reasons for maintaining a complete and properly prepared catalog.

It cannot be emphasized too strongly that what the designer wants is technical information rather than sales talk. While it is true that a certain amount of salesmanship is not objectionable, it should in general be constructive and to the point. The most effective approach will, in most cases, tend to illustrate the various uses for the products and, in particular, to call the designer's attention to adaptations of the products which he may have overlooked. Any truly useful product will sell itself if there is sufficient information presented to determine its adaptability to a particular use and its advantages over similar products made by another company.

Not to be overlooked in considering the advantages to the vendor is the consumer confidence built up by a good contact through a well-planned catalog of products. There is a certain amount of dependability implied by the fact that a vendor has been able to anticipate the needs of the customer to the extent of compiling the exact information regarding his product which would be of the utmost usefulness to the consumer. Many companies would take immediate steps to improve their cataloging and numbering of products if they were to hear some of the uncomplimentary remarks made by designers or draftsmen when they are attempting to obtain specific information from vendors' catalogs.

Effects of Inadequate Cataloging

Typical result of the lack of foresight on the part of manufacturers in not supplying adequate catalog information is a statement which was made recently by an executive of an aircraft company to a manufacturer: "We like your product, but because of the paucity of information, two groups in the design room have dropped its use." The first impression may be that this is rather an insignificant reason for not

using the product, but other factors must be considered.

Most of the aircraft manufacturers today are building planes for the United States Government. One of the government specifications states that "Drawings shall not be prepared for commercial standard parts and hardware which are used as manufactured for commercial use such as hinges, locks, starter switches, lamp bulbs, fan belts, roll and ball bearings, etc."

Again, in another paragraph, the same specification states that when "commercial and/or patented articles such as shock struts, motors, controls, instruments, etc., are used by the contractor exactly as produced by their manufacturer for commercial use or as specialties for the contractor, the manufacturer's name, address and identifying number shall be given on the assembly drawing. The contractor shall not make a drawing covering the article but shall secure for submission to the procuring agency an assembly drawing, and all sub-assembly and/or detail drawings prepared by the producer on his drawing form and under his drawing numbers to describe completely and identify all components by part number, name and quantity required."

The difficulty of satisfying the government requirements as well as the resulting confusion in attempting to use incompletely defined products often outweighs the advantages that would be gained by their use. Instead, the designer may choose to use a variation of design not embodying the product in question, or to use a competing product. Added to this is the usual hesitancy on an engineer's part to duplicate drawings of patented articles.

Need for Proper Numbering

One of the most serious objections to the cataloging method employed by many companies is the incompleteness of numbering systems used to identify products. A good numbering system should be of as much assistance in the handling of orders and the manufacture of parts within the producer's plant as it is in ordering, stocking and assembling the parts within the consumer's factory.

All major aircraft companies as well as the government services make extensive use of card-file and business-machine systems in controlling the supply and use of the many commercial parts required in modern aircraft. These systems depend heavily upon a complete, concise number identification of each and every part. Therefore, in presenting products to the industry, producers would do well to give careful consideration to their identification by simple but complete numbering systems. To meet government requirements, the identification should be limited to the use of combinations of letters, numbers and dashes not exceeding 15 places. When the identification exceeds this number of places, it is often not possible to handle it in the machines with which the government and aircraft industry are equipped.

Action by the N.A.S.C.

The National Aircraft Standards Committee, believing that complete information is the first step to standardization and realizing that the opinions of the numerous consumers of commercial items varied as to the information which they desired to have included in commercial parts catalogs, instituted a study to answer this question at least from the standpoint of the airplane manufacturing industry. A questionnaire was issued to the 32 prime contractors of airplanes who are members of this organization, listing the more obvious requirements to be fulfilled by a properly planned catalog and requesting comments as to the relative importance of these requirements. The companies were also asked to list any additional requirements that they believe should be included in such catalogs.

This questionnaire attempted to divide the requirements into two categories as well as to determine their respective importance. The requirements included in the first category were to be those which if omitted from parts catalogs would cause difficulty within the purchaser's plant. The second category was to consist of those requirements which are desirable but the omission of which could not be construed as causing difficulty in the application of the parts. Naturally, there was considerable over-lapping of these two categories, since all companies did not tend to assign the same importance to each requirement. The results of this questionnaire are listed below in the order of their respective importance.

Minimum Requirements for Catalogs

1. Parts should be identified by name and number.

2. Catalogs should carry the date of release. In the case of loose-leaf catalogs, the date of the latest page revision should appear on each page.

3. Sufficient information to allow practical application of the part should be shown, such as envelope size, tolerances, location and size of electric, hydraulic, pneumatic or other connections.

4. Changed parts should be given new numbers or dash numbers unless dimensionally and functionally interchangeable.

5. Maximum strength or capacity of parts should be specified.

6. Type and specification number of the material from which the part is fabricated should be shown. Government drawing or specification numbers to which the part may be manufactured should also be noted when they are applicable.

7. Method of interpreting coded part numbers should be specified.

8. All pages should be numbered.

9. Parts having general government approval for use on aircraft should be noted.

10. Catalogs should be carefully indexed.

11. Special information necessary for proper installation of the parts should be specified.

12. Information regarding the proper method of ordering should be included when necessary.

13. The accurate actual weight of all parts should be shown. If at any time the calculated weight is used in lieu of the actual weight, it should be so specified.

Desirable Additional Features

1. Catalogs should have an identifying number.

2. Special tools necessary to install parts should be listed.

3. Related drawings giving more detailed information should be referenced when available.

4. Catalogs should be approximately 8½ x 11 in. to facilitate filing.

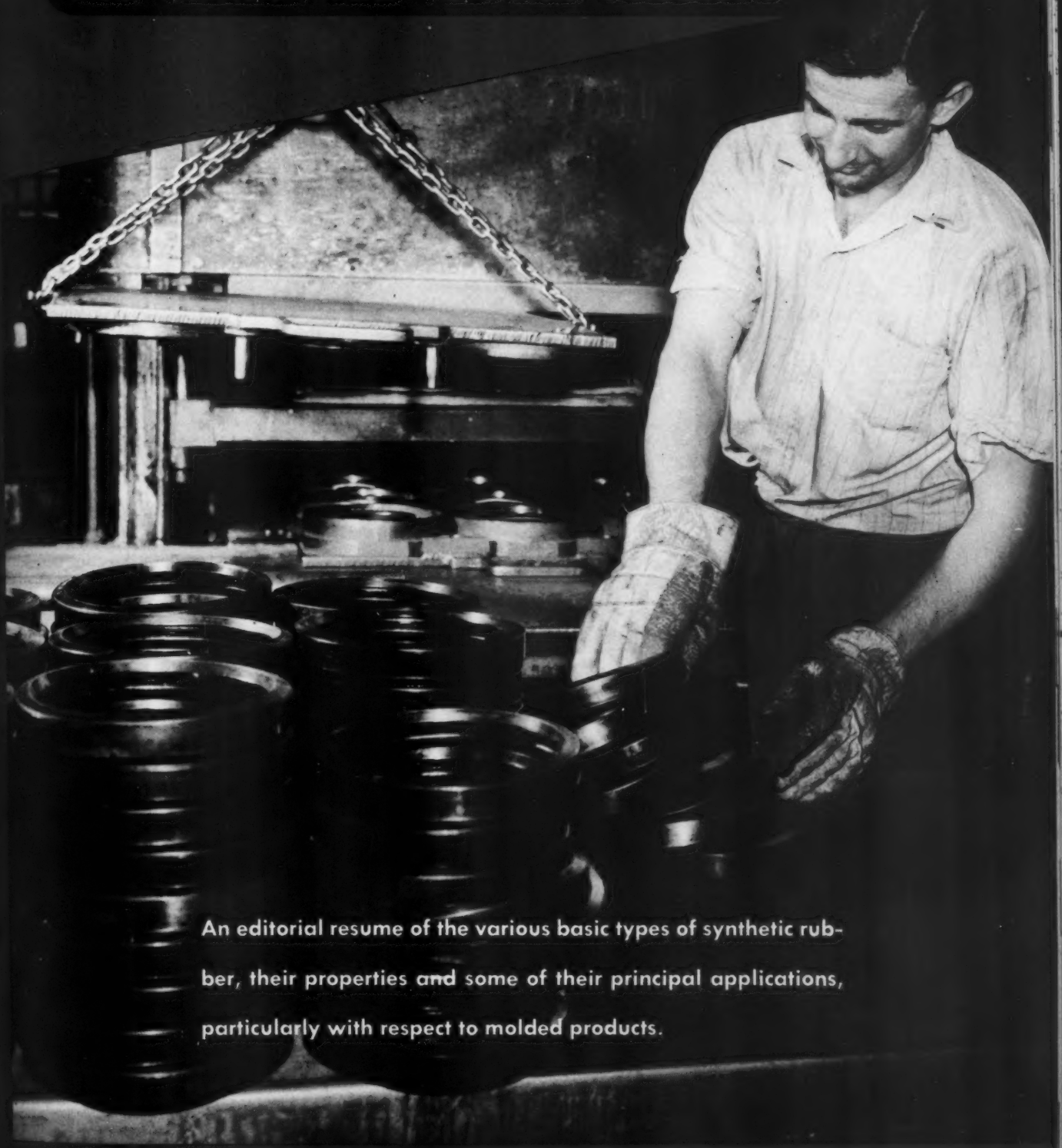
Other Items

There are a number of additional items which are sometimes associated with the cataloging of products, such as cutaway views or the more elaborate overlay method of showing internal construction; individual tracing sheets or templates for the convenience of draftsmen; tables and charts on performance, etc. The necessity or desirability of including these in the catalog will depend mostly upon the individual case.

Listing of prices is often a matter of concern in compiling catalogs. Because of the complications involving discounts for quantity purchases, the fluctuation of prices and other variations which enter into the price schedule, it is believed desirable to recommend that in most cases this information be supplied as a supplement to the catalog or listed in an independent document.

Synthetic RUBBER

FOR PRESENT AND POSTWAR PRODUCTS



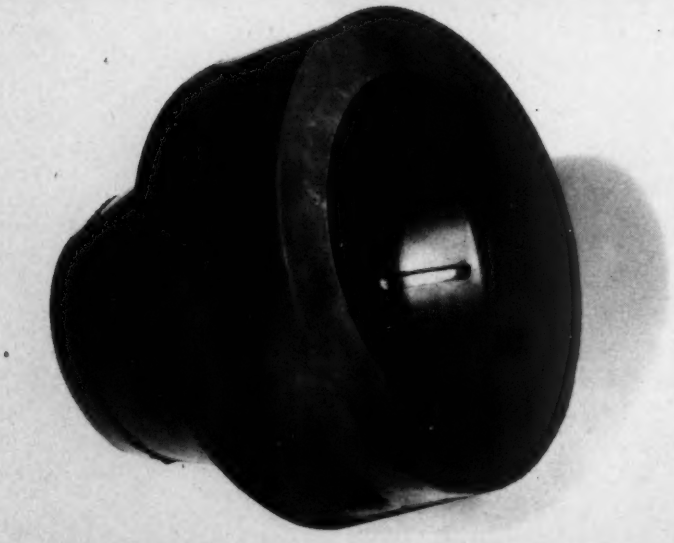
An editorial resume of the various basic types of synthetic rubber, their properties and some of their principal applications, particularly with respect to molded products.

Synthetic RUBBER

by STANLEY A. KOGUT

Hose connectors can be molded in various shapes, combinations of sizes and degrees of flexibility. *Wright Aeronautical Corp.*

Washers are among the plumbing specialty items that can be easily molded from any of the types of synthetic rubber. *U. S. Rubber Co.*



Oil well packer, molded of a hard compound of Buna N, must be especially resistant to oil swelling. *Stanco Distributors, Inc.*

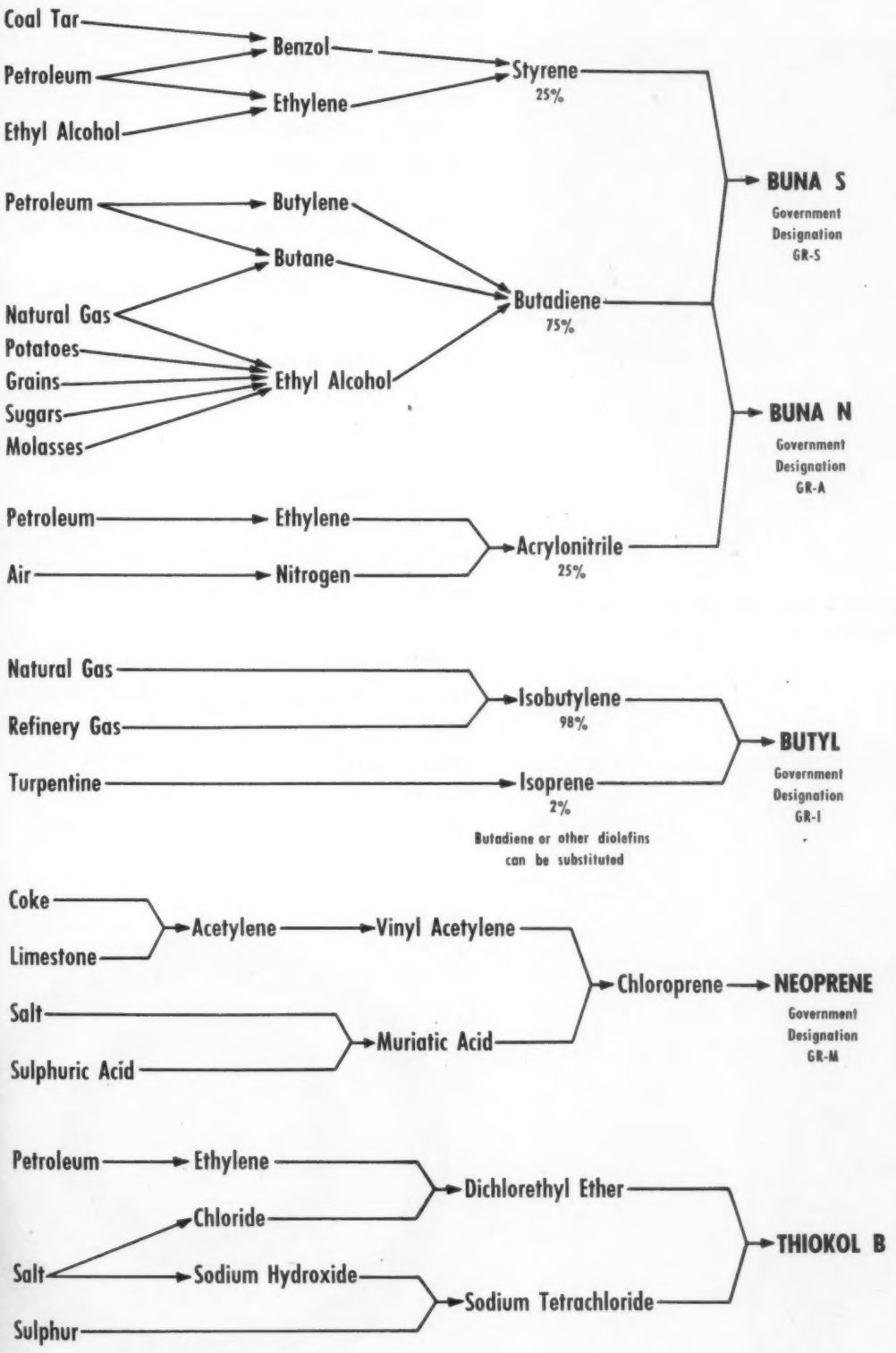
SYNTHETIC RUBBER is a generic name for those compounded materials that possess to a marked degree the outstanding characteristics of natural rubber—mainly elasticity and the ability to be vulcanized. They can be calendered, molded, extruded and otherwise worked or processed the same as natural rubber. Details of the operations and the results obtained vary considerably between different types of synthetic and between synthetic and natural rubber.

Nearly all synthetic rubbers can be compounded with each other and with natural rubber. Butyl is the principal exception.

Selection of the proper type of synthetic rubber is not a simple procedure because the properties of a particular material depend on many variables. Frequently, certain desirable properties must be sacrificed to increase a property more important for the particular application.

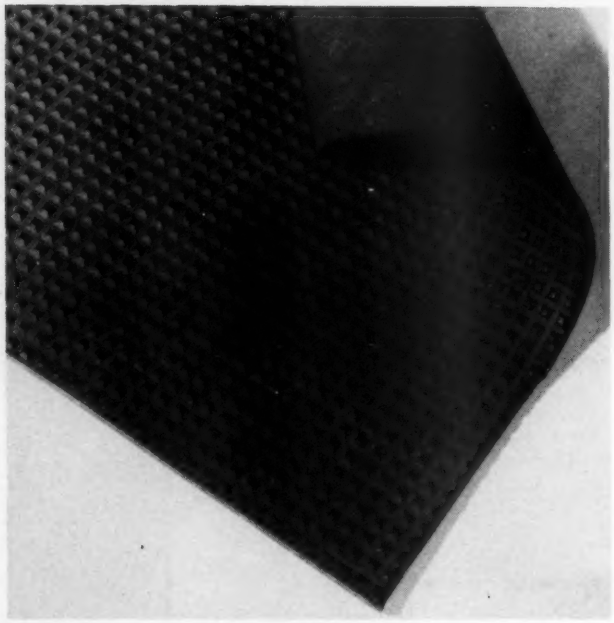
Spark plug shields are molded of Buna N for good oil resistance or of Butyl for good electrical properties. *Stanco Distributors, Inc.*

THE FIVE BASIC TYPES OF SYNTHETIC RUBBER AND THEIR DERIVATION

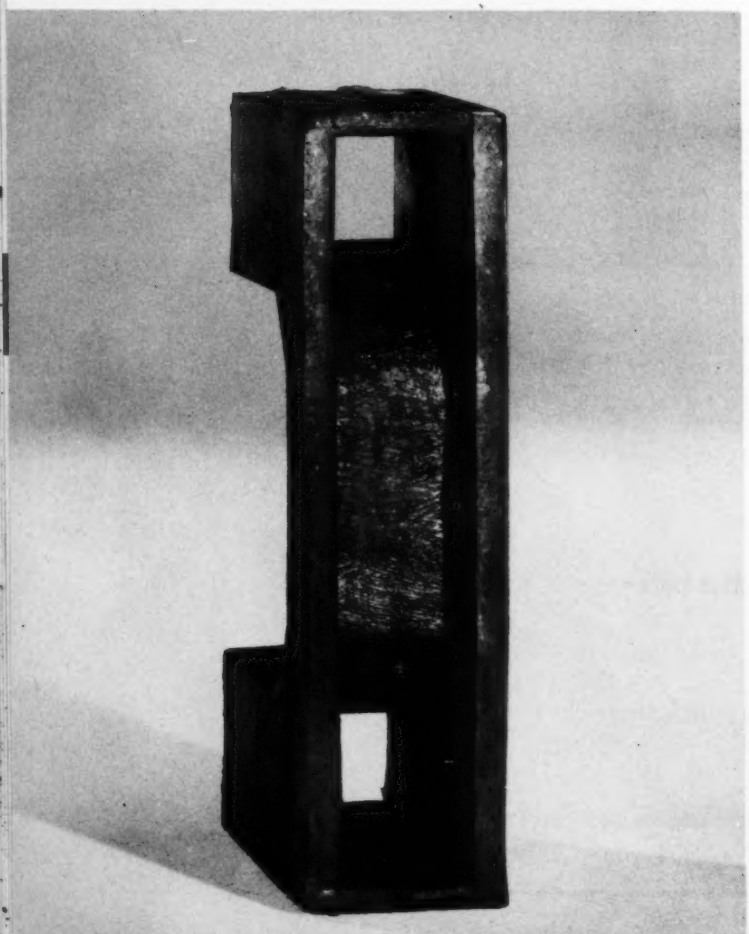


Each basic type is available in numerous compounds especially suited to specific applications.

BUNA S



Floor covering can be made in nearly all types of synthetic rubber, depending on service conditions. *Stanco Distributors, Inc.*



Bumpers can be made of Buna S in cast iron molds. Electroplating the mold produces smooth surfaces. *Republic Aviation Corp.*

BUNA S, often referred to as GRS, meaning "Government Rubber Styrene Type," has been called a "general-purpose" rubber because it has no marked superiority over natural rubber that would make it suitable for special uses. In many respects it is slightly inferior to the natural material and in others it is somewhat better.

CHARACTERISTICS:—Can be mixed and processed with not too much difficulty by conventional rubber methods.

Temperature and cure times are similar to those of natural rubber and tendency to scorch during processing is not as great.

Resists aging in the oxygen bomb and the hot air oven.

Pure gum stocks have low tensile strength and inferior physical properties.

Good range of colors is obtainable.

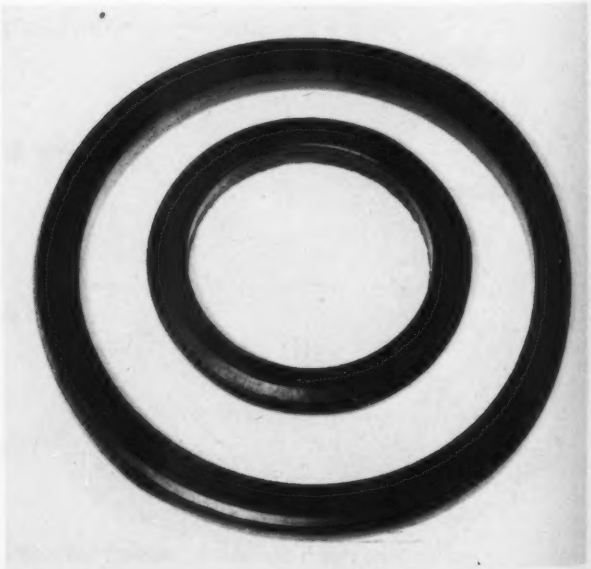
Water absorption is about 65 percent that of natural rubber.

Excellent resistance to heat, but only in the absence of severe flexing.

Vulcanizates show excellent resistance to cracks from flexing only so long as the material being flexed is perfect. Any cracks, regardless of size, will grow rapidly when the material is flexed.

Deteriorates in sunlight. Even indirect sunlight causes deterioration. When the material is stretched these weaknesses become more acute. A crack resulting from sun check may in short order be flexed to a sizeable rupture.

Compared to natural rubber Buna S has a lack of



Seals for equipment that handles liquids are molded for specific service requirements. *Stanco Distributors, Inc.*

tackiness, low tensile strength and low tear resistance, and repeated flexure develops high heat.

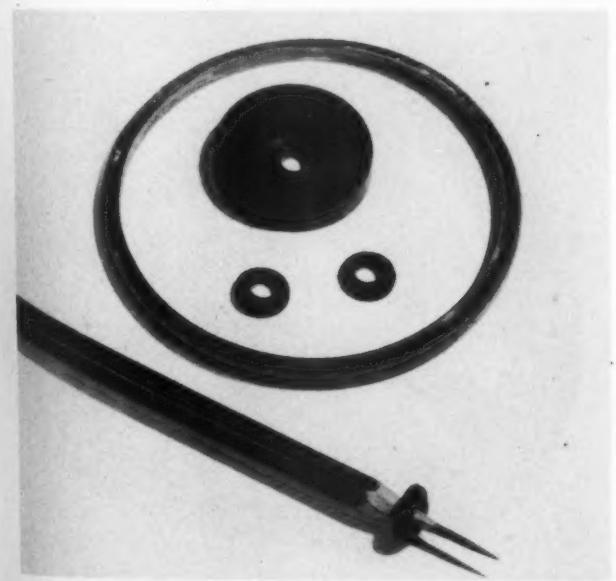
COMPOUNDS:—Buna S is often compounded with natural rubber, guayule or reclaimed rubber. Natural rubber and guayule are blended with it to obtain tackiness and reclaim has been found to help in the calendering process. When compounded, the tensile strength is as high as 2,500 lb. per sq. in. and elongation is lower than that of rubber. Resistance to oxidation and heat aging are superior to that of natural rubber—except that Buna S has a tendency to become hard and brittle.

APPLICATIONS:—Tires, belts and belting, hose, packings, extruded parts, molded goods.

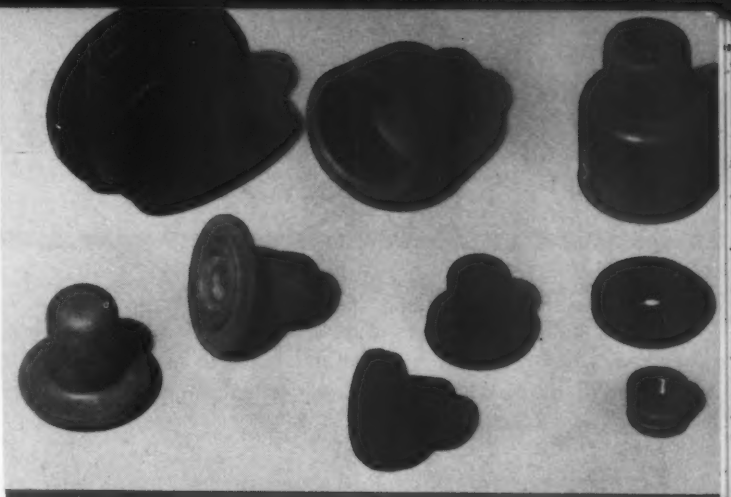
COMPARISON OF TYPICAL PROPERTIES*

	Buna S	Natural Rubber
Typical tensile strength, lb. per sq. in.	2,000	3,800
Specific gravity	0.94	0.93
Color range	Fair	Excellent
Resistance to abrasion	Good	Excellent
heat generation through hysteresis	Fair	Excellent
swell in oil	Poor	Poor

*Special compounding may increase specific properties.

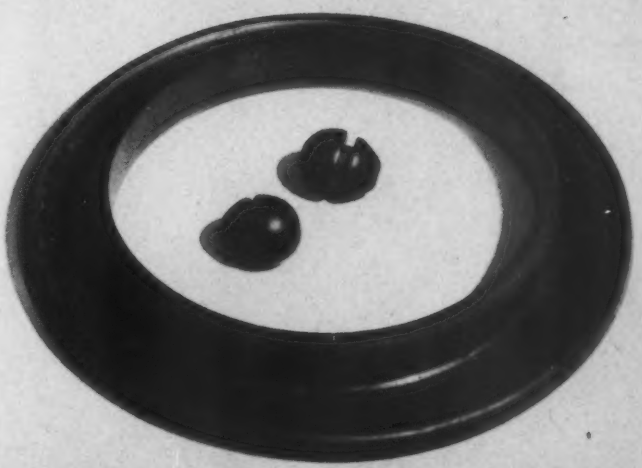


Bushings made from Buna S synthetic rubber are molded in an unlimited variety of shapes and sizes. *General Motors Corp.*



Stoppers and washers are molded in various sizes and shapes. Note threaded metal insert at lower right. *U. S. Rubber Co.*

Vibration-resistant unit molded of Buna S has metal parts bonded on the ends to facilitate mounting. *De Lisser Machine & Tool Co.*



Bumpers to absorb shocks can be molded of Buna S synthetic rubber in any desired shape and size. *Grumman Aircraft Engineering Corp.*

NEOPRENE

NEOPRENE's outstanding characteristic is oil resistance, which makes it particularly suitable for such applications as oil hose and processing equipment that involves the use of oil.

CHARACTERISTICS:—Resists oil deterioration, solvents, sunlight, ozone, flexing, heat and flame.

Various types resist swelling in water, gas diffusion, oil and high temperature.

High adhesive strength.

Can be vulcanized at room temperature.

Resists permanent set.

Wide range of colors; can be made into light colors and even white.

Physical characteristics such as tensile strength and elongation while not the equal of rubber have a definite resemblance. Neoprene can be compounded to a tensile strength of 2,500 lb. per sq. in. and an elongation of 900 percent.

Tear resistance is slightly less than that of rubber. Under normal conditions Neoprene is more susceptible to abrasion than rubber. Recovery from distortion is complete but not as rapid as that of rubber. Special types are excellent for applications where heat is encountered.

While Neoprene is known for its resistance to mineral oils, these oils swell it; but even in a swollen condition original physical characteristics are largely retained. Vegetable oils such as cottonseed, olive, linseed and cocoanut are handled satisfactorily by the material.

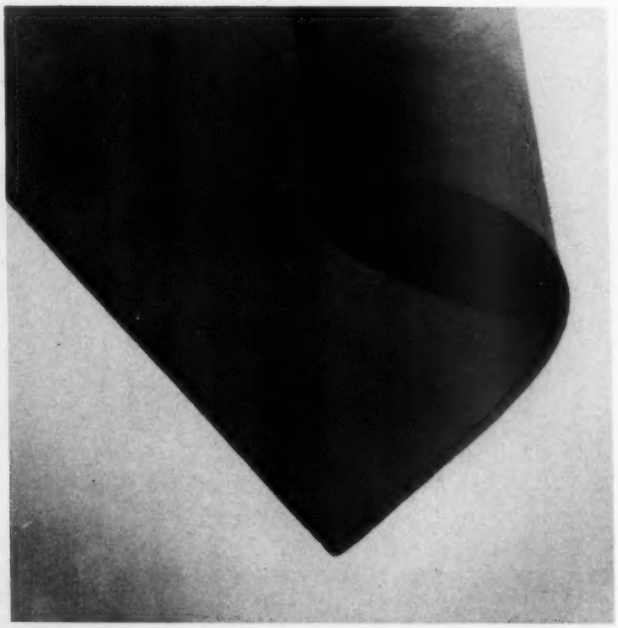
Can be made into sponge.

Neoprene is "flame-proof"—that is, it will burn if placed in a flame but will not support combustion. This property makes it superior to other synthetics where the possibility of fire exists.

TYPES OF NEOPRENE used for specific properties:

Flex Resistance — E, GN
High-Temperature Resistance — GN, E, ILS
Freeze Resistance — FR
Flame Resistance — All types
Sunlight Resistance — All types
Ozone Resistance — All types
Oil Resistance — All types
Low Oil Swell — ILS
Low Water Swell — FR, ILS, E
Diffusion Resistance — ILS
Low Compression Set — FR, ILS
High Tensile Strength — GN, CG, T
High Resilience — FR, GN

COMPOUNDING: — Various types of Neoprene can be compounded with one another. The physical charac-



Sponge sheet of Neoprene can have cells interconnecting, as in an ordinary sponge, or as separate units. *Edo Aircraft Corp.*

Goggle mounts are molded of Neoprene sponge for resistance to perspiration and body oils. *Bausch & Lomb Optical Co.*

teristics of the resulting material will resemble those of each type in proportion to the amounts used. For instance, an FR-ILS mixture may be desired for low oil swell and freeze resistance. A GN-FR Neoprene could be used for applications where resistance to tearing and cold are desired.

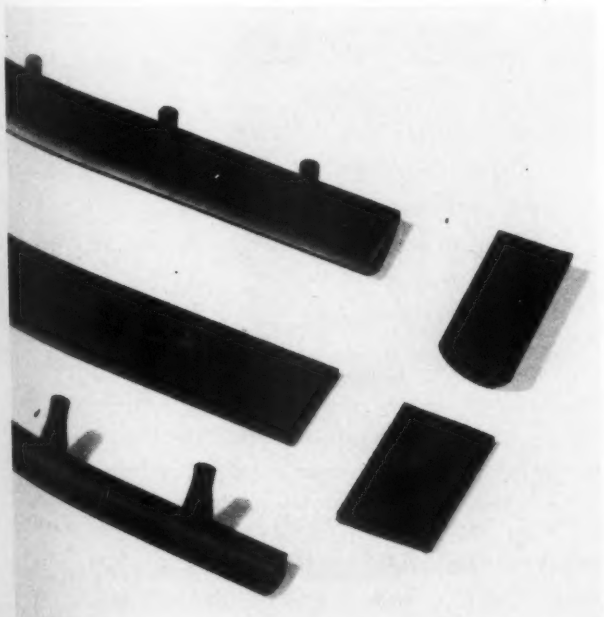
In all cases of blends, however, the resulting material is a compromise of the outstanding characteristics of each incorporated type. In other words, the addition of FR to ILS to increase freeze resistance will sacrifice oil resistance. Conversely, ILS added to FR stock will increase oil resistance but reduce freeze resistance.

APPLICATIONS: —Tires, wire covering, oil delivery hose, gaskets, diaphragms.

COMPARISON OF TYPICAL PROPERTIES*

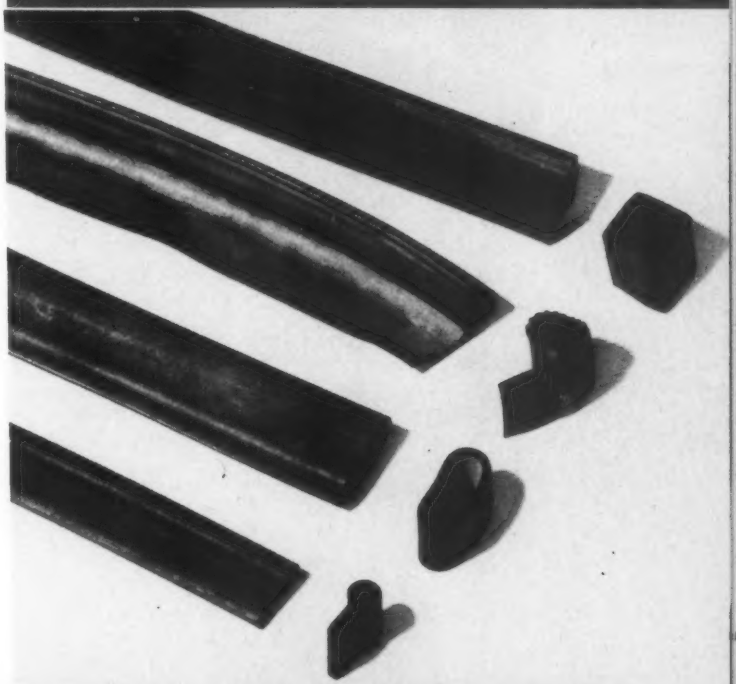
	Neoprene	Natural Rubber
Typical tensile strength, lb. per sq. in.	2,500	3,800
Specific gravity	1.25	0.93
Color range	Good	Excellent
Resistance to abrasion	Excellent	Excellent
heat generation through hysteresis	Fair	Excellent
swell in oil	Good	Poor

*Special compounding may increase specific properties.



Sealing strips made of Neoprene have buttons molded integrally with the strip to allow for quick mounting. Glenn L. Martin Co.

Windows and windshields of high-altitude aircraft are molded from Neoprene FR which resists cold. General Motors Corp.



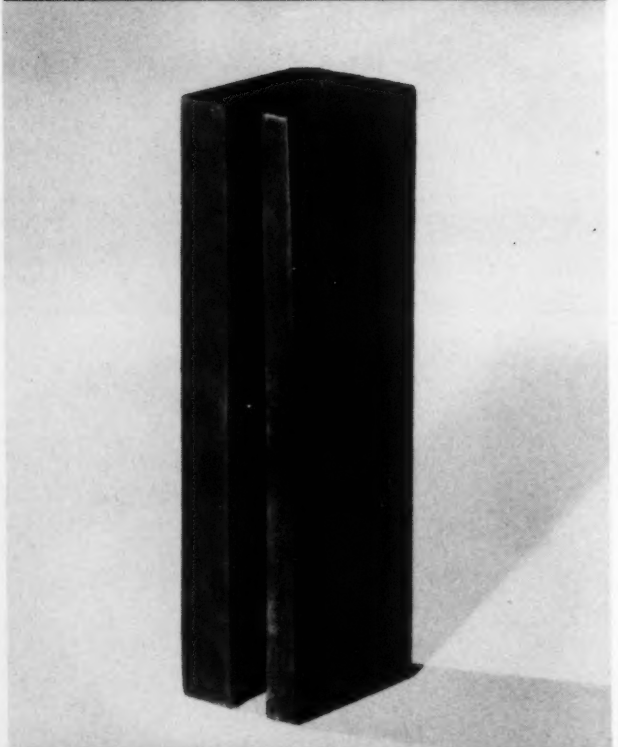
Bumper, weather and cable strip is extruded from Neoprene in a variety of cross-sections and sizes. Republic Aviation Corp.

Dust connectors used on aircraft motors can be made of Neoprene formed by wrapping and molding. Grumman Aircraft Engineering Corp.

BUTYL

Tank ball with brass threaded plug inserted is molded around a metal core that is easily removed after forming. U. S. Rubber Co.

Bumper mounting, for use on miner's lamps to absorb shocks, can be molded of Butyl synthetic rubber. U. S. Rubber Co.



Channel extruded from Butyl synthetic rubber is useful where resistance to aging is desired. Republic Aviation Corp.

BUTYL is noted for its resistance to diffusion of gases, which makes it more "air-tight" than natural rubber. By varying the kind and amount of diolefin used in making Butyl, specific properties can be developed, although basic characteristics are retained. The chemical stability of Butyl also accounts for many of its applications. It has tensile strength in the pure gum state of about 800 lb. per sq. in. This can be increased to about 2,500 lb. per sq. in. by compounding. Butyl cannot be used in conjunction with other synthetics or natural rubber.

CHARACTERISTICS: — Excellent age and oxygen resistance.

Highly impermeable to gases.

Low water absorption.

Good dielectric properties.

Resistant to acids, particularly sulphuric and nitric, and alkalis.

Excellent flex resistance.

Low rebound at room temperature.

VOLUME INCREASE – THREE MONTHS IMMERSION

	Rapeseed Oil	Soybean Oil	Lard Oil	Olive Oil	Oleic Acid	Cotton-seed Oil
Butyl	5.5	4.0	10.0	11.8	108.0	5.4
Rubber	106.0	199.0	111.0	121.0	196.0	84.0
Buna N	0.4	0.0	0.7	2.9	35.3	0.9

High rebound at elevated temperatures.

Good heat resistance.

Swells in petroleum or coal tar solvents the same as natural rubber.

Does not swell in most vegetable and animal fats and oils.

Can be frictioned, skimmed or sheeted with little difficulty and extrudes rapidly and smoothly.

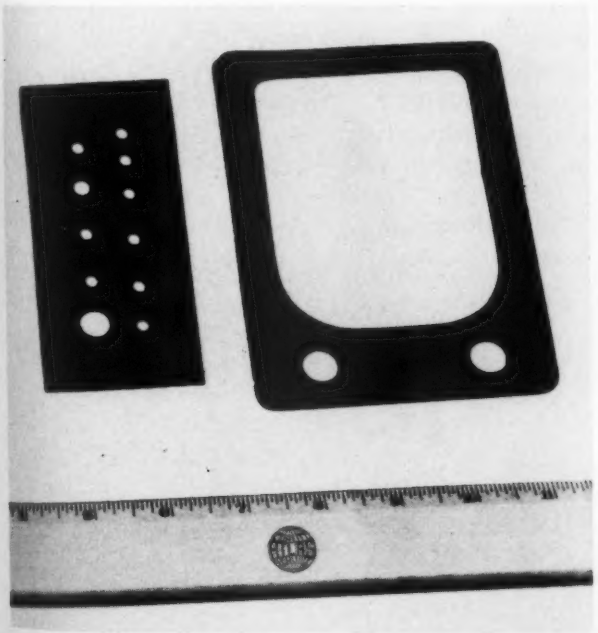
Has a hardness range of from 20 to 85 durometer and can have an elongation of over 800 percent.

APPLICATIONS: — Inner tubes, tank linings, hose, balloon cloth, life rafts, rubberized clothing.

COMPARISON OF TYPICAL PROPERTIES*

	Butyl	Natural Rubber
Typical tensile strength, lb. per sq. in.	2,500	3,800
Specific gravity	0.91	0.93
Color range	Good	Excellent
Resistance to abrasion	Fair	Excellent
heat generation through hysteresis	Excellent	Excellent
swell in oil	Poor	Poor

*Special compounding may improve specific properties.



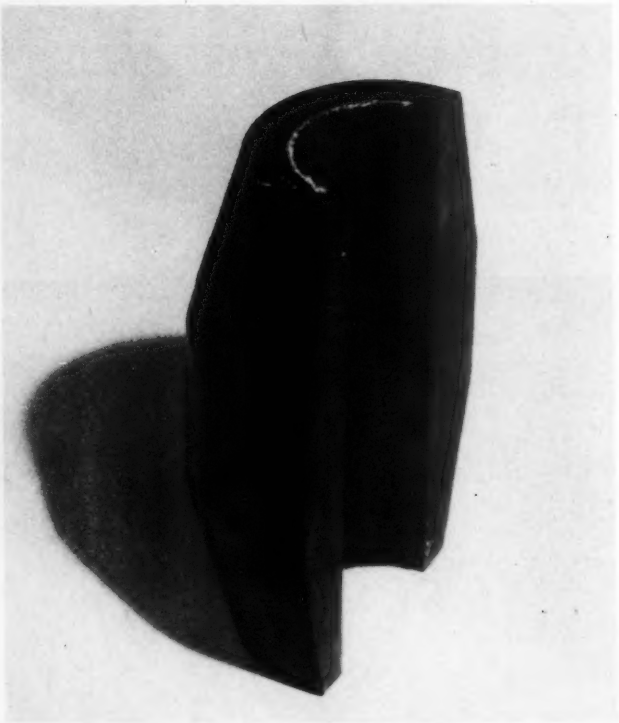
Gaskets and fume seals are die cut from Butyl sheet because the material is impermeable to gases. *Republic Aviation Corp.*

Metal adhesion properties of most synthetic rubbers are good, so that molded parts can have metal inserts. *Stanco Distributors, Inc.*

Mountings for tufts of bristles to form brushes withstand water and aging when molded of Butyl synthetic rubber. *Moran Bros.*

Milking inflations are being experimentally molded of Butyl, which resists animal fats and oils, and tearing. *Stanco Distributors, Inc.*

BUNA N



Swab, half of which is shown here, used in oil-well drilling is molded of fabric impregnated with Buna N synthetic rubber. U. S. Rubber Co.

Diaphragms are molded from Buna N synthetic rubber because of its good chemical resistance and other desirable properties.

BUNA N is inherently oil resistant, like Neoprene. The amount of acrylonitrile used in manufacture affects the relationship and exact values of the inherent qualities of the material.

TYPES OF BUNA N: — Several types of Buna N are manufactured and marketed under trade names of which the following are representative:

Hycar OR
Perbunan
Chemigum
Butaprene
Thiokol RD

CHARACTERISTICS: — Good physical properties.

Great resistance to swell in petroleum products.

Can be compounded for excellent abrasion resistance, high tensile strength, good heat resistance and good cold flow properties.

Outstanding resistance to carbon tetrachloride.

Generally, an increase in the nitrile content increases resistance to swelling in gasoline, but there is a corresponding decrease in resistance to cold.

Recently, Buna N has been blended with natural or reclaimed rubber, or the vinyl plastics, resulting in blended materials with excellent properties for specialized purposes.

Buna N can be made into "hard rubber" with 10,000 lb. tensile strength. Sponges are superior to those made of natural rubber.

PRIMARY PROPERTY of Buna N is its resistance to the action of gasoline, petroleum and aliphatic hydrocarbons, such as mineral oils, animal fats and oils, vegetable oils, printing inks and paint dryers. It can be used where resistance to aging, high temperatures, freezing and abrasion is required. It is soluble in aromatics and chlorinated hydrocarbons such as benzol, naphtha and toluol. Ketones, organic acids, alcohol and esters swell Buna N more than they swell natural rubber. It is particularly good where both heat and oil are encountered.

APPLICATIONS: — Molded goods, tank linings, conveyo belts, hose, cable, packings, diaphragms.

COMPARISON OF TYPICAL PROPERTIES*

	Buna N	Natural Rubber
Tensile strength, lb. per sq. in.	2,500	3,800
Specific gravity	1.00	0.93
Adhesion to fabrics	Good	Excellent
Resistance to swell in lubricating oil	Excellent	Poor
oil deterioration	Excellent	Poor
aromatics	Fair	Poor
lacquer solvents	Fair	Poor
heat	Excellent	Good
aging	Excellent	Poor
oxidation	Poor	Poor

*Special compounds may improve specific properties.

RESISTANCE OF TYPICAL STOCK TO VARIOUS OILS

Original tensile strength 2,120 lb. per sq. in. and elongation 520 percent

	AFTER ONE WEEK			AFTER THREE WEEKS		
	Tensile Strength, lb. per sq. in.	Percent Tensile Strength Retained	Elongation, percent	Tensile Strength, lb. per sq. in.	Percent Tensile Strength Retained	Elongation, percent
Cottonseed Oil	2,000	94	400	1,960	92	400
Linseed Oil	1,790	84	470	2,030	95	970
Olive Oil	1,930	91	480	1,940	91	500
Rapeseed Oil	2,390	107	500	1,910	90	500
Soybean Oil	1,850	87	370	1,530	72	350
Lard Oil	1,990	94	450	2,020	95	450

RESISTANCE TO SWELLING

Percent swell 16 days at room temperature

15 percent Benzol, 85 percent Varsol #1	37.5
SAE Low Motor Oil	6.0
Cyclohexane	20.0
Distilled Water	2.3
Cottonseed Oil	5.0
Turpentine	36.7
Methyl Alcohol	12.0
Benzene	220.0
Amyl Acetate	137.0
Acetone	142.0
Ethylene Dichloride	317.0

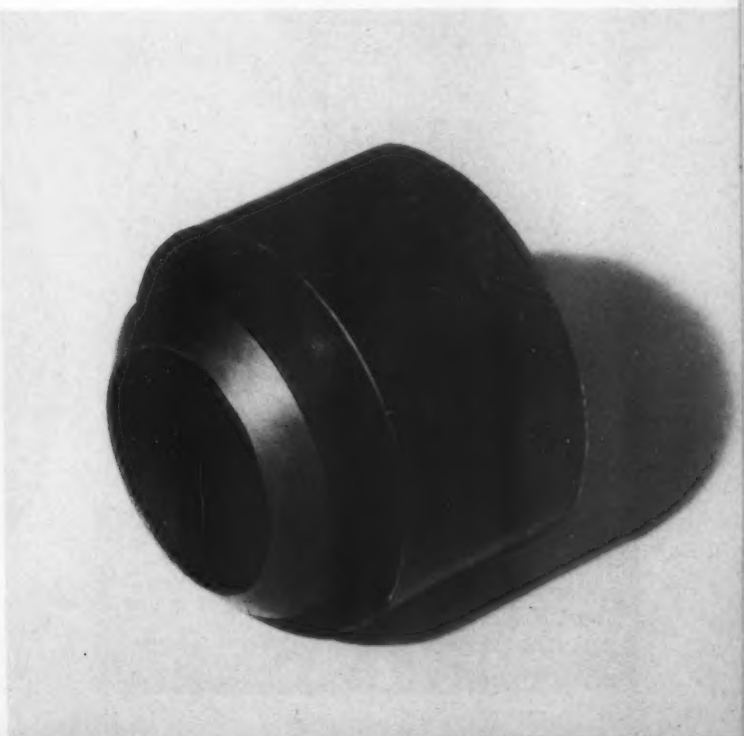
EFFECT OF TEMPERATURE ON PHYSICAL PROPERTIES

Typical Stock, Hot-Air Oven, 250 deg. F.

	Original Properties	Four Days	Seven Days
Tensile Strength, lb. per sq. in.	2,380	2,590	2,370
Elongation, percent	360	330	250
Durometer Hardness	66	69	70
Percent of Original Tensile Strength Retained	--	109	100
Percent of Original Elongation Retained	--	92	70

These values show excellent resistance to heat. The general tendency of rubber and rubber substitutes is to become hard with heat.

oulic gaskets molded of Buna N synthetic rubber are used as integral ts of flexible couplings for pipe. U. S. Rubber Co.



Gland packings used in oil-field work are molded of Buna N and duck because of the oil resistance of the synthetic. U. S. Rubber Co.

THIOKOL

THIOKOL is a special-purpose synthetic that is also noted for resistance to the chemical action of oils. It is used in many mechanical applications.

CHARACTERISTICS: — Resists gasoline, kerosene, oils and lacquer solvents.

Resists sunlight, ozone, aging.

Has poor tear and abrasion resistance.

Electrical insulating properties are fair.

Vulcanized by heat alone.

Properties are stable in cold but fall off at higher temperatures.

Resistance to water swell and to deterioration in mineral oil is excellent.

Has perceptible odor, but recent compounds have shown considerable improvement in this respect.

Air duct hose made of Thiokol by wrapping is light and flexible because of the construction. *Murray Corp.*

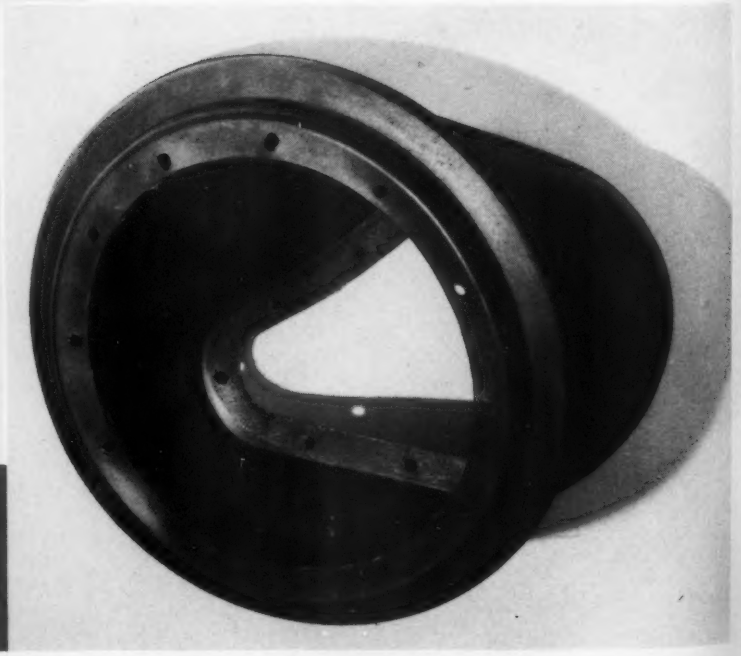
COMPARISON OF TYPICAL PROPERTIES*

	Thiokol	Natural Rubber
Typical tensile strength, lb. per sq. in.	1,500	3,800
Specific gravity	1.35	0.93
Resistance to swell in oil	Excellent	Poor
abrasion	Poor	Excellent
heat generation through hysteresis	Fair	Excellent
water swell	Excellent	Fair

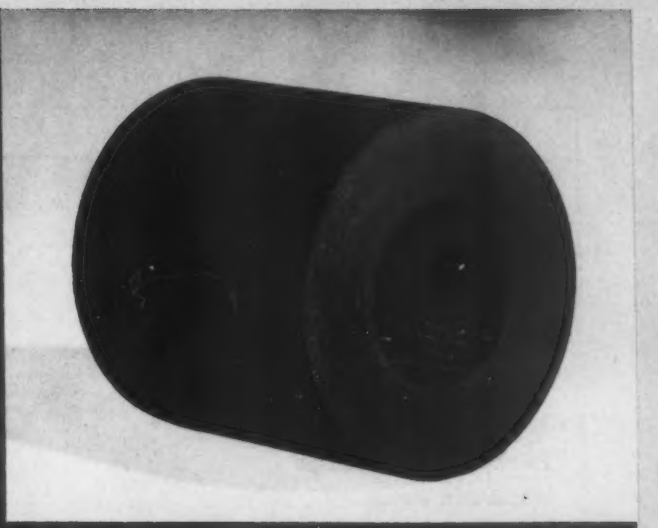
*Special compounds may improve specific properties.

Piping made with a synthetic rubber core and cover has impregnated fabric as a reinforcement.

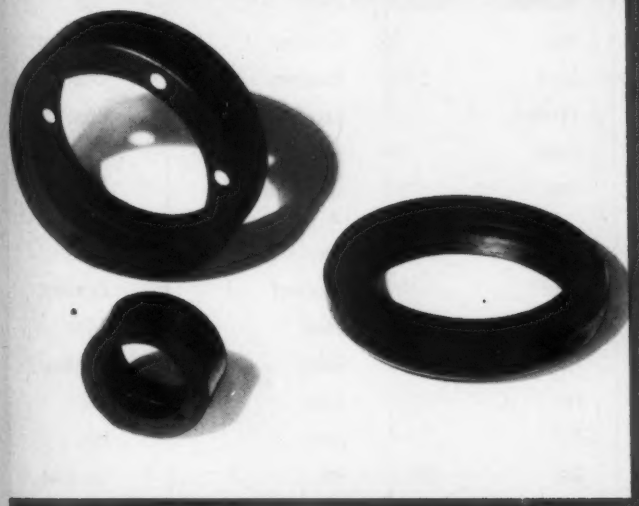
Scuppers for fueling aircraft are molded from Thiokol for gasoline resistance. *Douglas Aircraft Corp.*



Flexible hose used for gas masks is hard to collapse because of the concentric rings. Stanco Distributors, Inc.

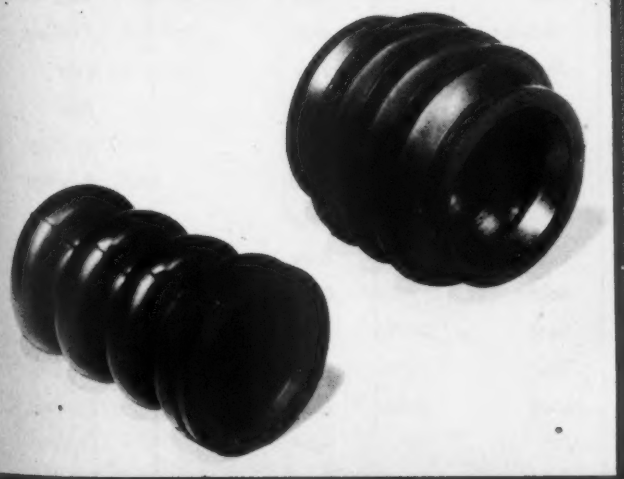


Printing rollers have calendered sheet laminated to a cushion molded on a metal shaft Stanco Distributors, Inc.



Gaskets and seals are molded of synthetic rubber for flexible connections used in pipe lines. Stanco Distributors, Inc.

Oil seals are often molded of hard material that has a degree of resilience and flexibility. Stanco Distributors, Inc.



Boots cover mechanical connections of shafts to keep dust out and oil and grease in. Stanco Distributors, Inc.

Rollers can be molded around metal cores from almost any type of synthetic rubber. Aero Affiliates

COMPARATIVE PROPERTIES OF SYNTHETIC RUBBER

PROPERTY	BUNA S	NEOPRENE	BUTYL
Typical Tensile Strength, lb. per sq. in.	2,000	2,500	2,500
Elongation	Good	Excellent	Excellent
Recovery (Resistance to Permanent Set)	Good	Good	Poor
Specific Gravity	0.94	1.25	0.91
Durometer Hardness	25-100	20-90	20-85
Freedom from Odor	Fair	Fair	Fair
Resistance to Cold Flow	Good	Good	Fair
Electrical Insulating Properties	Excellent	Poor	Excellent
Vulcanization Method	Heat and Sulphur	Heat Alone	Heat and Sulphur
Color Range	Good	Good	Good
Conductivity	Fair	Good	Fair
Resistance to Corona Cracking	Fair	Excellent	Good
Hot Flow	Excellent	Fair	Fair
Sunlight	Poor	Excellent	Excellent
Ozone	Good	Excellent	Excellent
Aging	Excellent	Excellent	Excellent
Heat	Good	Good	Excellent
Flame	Poor	Will Burn Only in Flame—Good	Poor
Abrasion	Good	Excellent	Fair
Flexing	Good	Excellent	Excellent
Corrosive Agents	Good	Good	Good
Gas Diffusion	Fair	Good	Excellent
Tearing	Fair	Good	Good
Cutting	Fair	Good	Fair
Heat Generation Through Hysteresis	Fair	Fair	Excellent
Deterioration in Mineral Oil	Poor	Good	Poor
Lacquer Thinners	Poor	Poor	
Carbon Bisulfide		Poor	
Carbon Tetrachloride	Poor	Poor	Poor
Water Swell	Excellent	Good	Excellent
"Ring" Hydrocarbons (Aromatics)	Poor	Poor	Poor
Petroleum Products	Poor	Good	Poor
Oxidizing Solutions	Poor	Poor	Excellent
Salts	Good	Good	Excellent
Alkalis	Good	Good	Good
Acids	Good	Good	Excellent
Stability of Properties in Heat	Good	Excellent	Good
Stability of Properties in Cold	Good	Good	Good
Suitability to Use with Food Products	Good	Good	Excellent
Metal Adhesion	Good	Excellent	Excellent
Fabric Adhesion	Fair	Good	Excellent
Workability	Good	Good	Excellent
Storability	Excellent	Excellent	Excellent

UBBERS

BUNA N	THIOKOL	NATURAL RUBBER
500	1,500	3,800
ood	Poor	Excellent
ood	Poor	Excellent
90	1.35	0.93
0-100	20-80	10-100
oor	Poor	Good
xcellent	Poor	Excellent
oor	Fair	Excellent
eat and Sulphur	Heat Alone	Heat and Sulphur
ood	Poor	Excellent
oor	Fair	Fair
oor	Excellent	Poor
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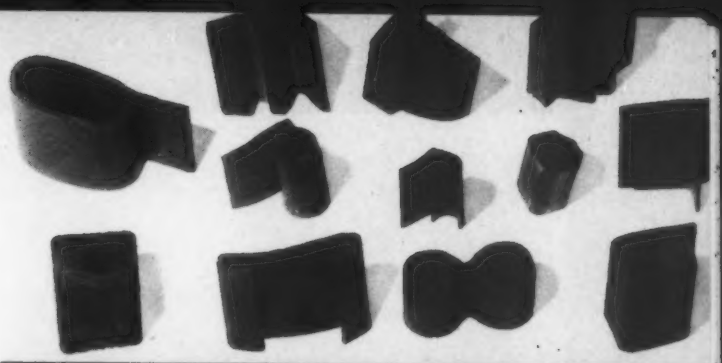
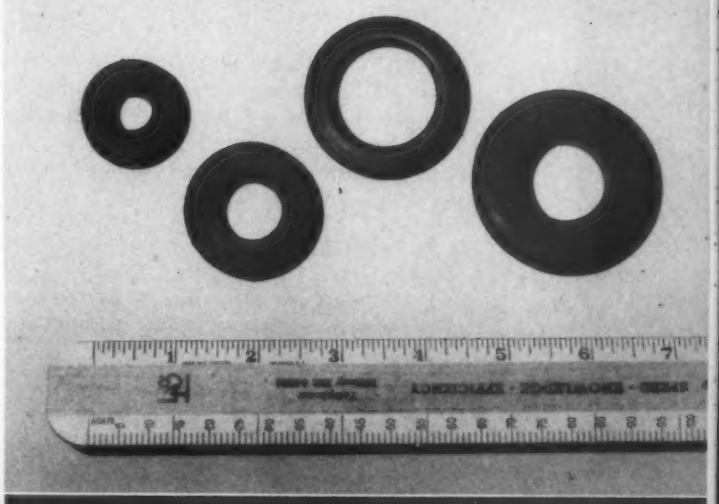
	Fair	
	Good	Poor
xcellent	Excellent	Fair
	Excellent	Poor
xcellent	Excellent	Poor
oor	Poor	Poor
ood	Good	Good
ood	Good	Good
ood	Good	Good
xcellent	Poor	Good
ood	Excellent	Excellent
ood	Unsuitable	Excellent
xcellent	Poor	Excellent
ood	Fair	Excellent
ood	Fair	Good
xcellent	Excellent	Fair

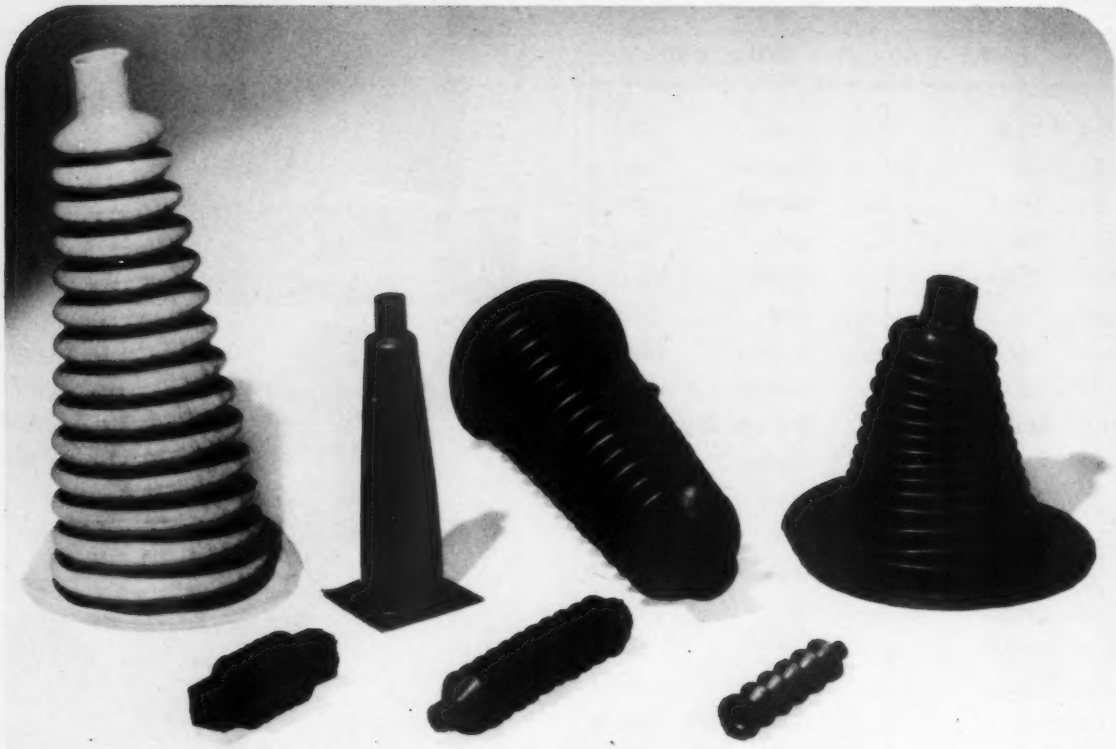


Channel, bumper and weather strips are extruded in various cross-sections and sizes for specific conditions. *U. S. Rubber Co.*

Connectors molded of synthetic rubber have numerous applications for hose and pipe that handle liquids or air. *Republic Aviation Corp.*



Grommets are molded from all types of synthetic rubber to suit any specific conditons. Choice of size and shape is unlimited.



Bellows and boots used to prevent fumes from entering cabins of aircraft are made from synthetic rubber by molding or dipping.

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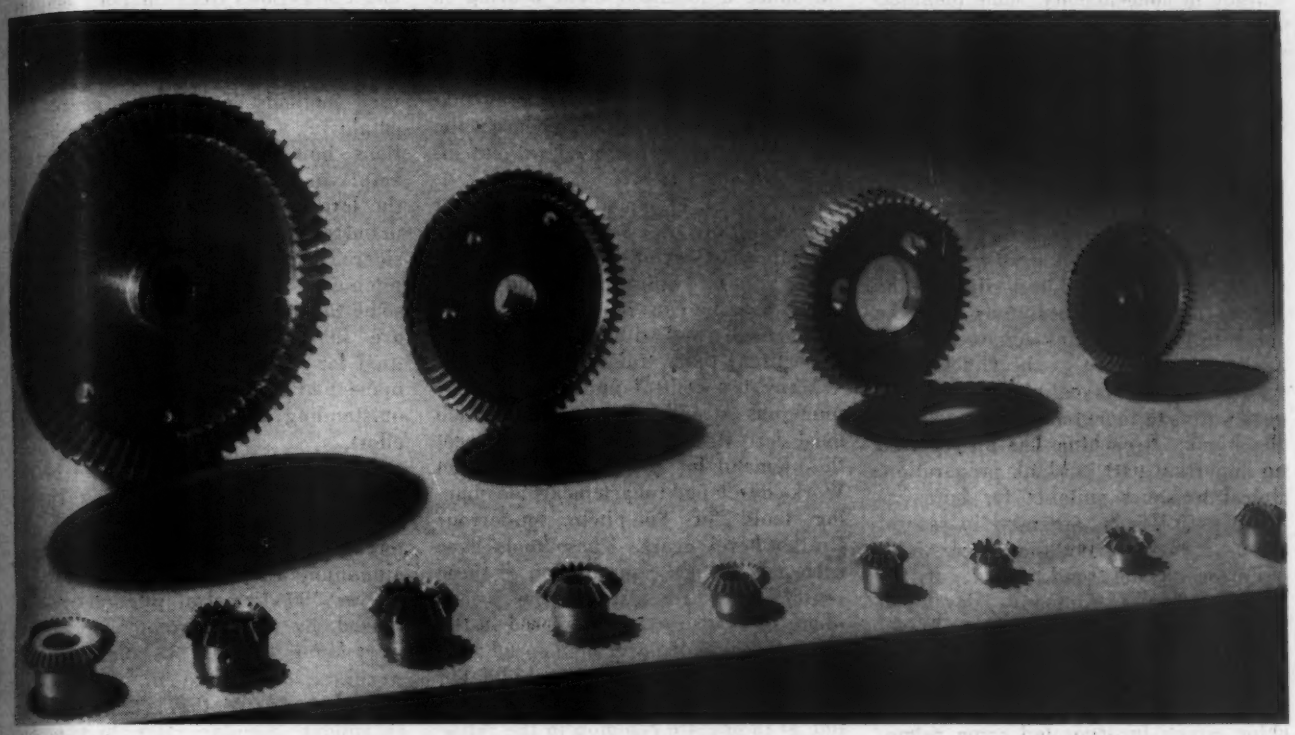


Advantages and Specifications Of Fine-Pitch Gears

Gears having 30 diametral pitch and finer, and employing the involute tooth form are discussed. Recent developments in gear cutters, shavers and inspection tools for manufacturing fine-pitch gears are reviewed. Common errors in the design of such gears are pointed out.

ONE of the many problems arising out of the war effort was the production of large quantities of precision fine-pitch gears used in innumerable devices, such as radar, fire director units, height and range finders, and telescopes. Fine-pitch gears are commonly thought of as small in diameter, not unlike those used in a watch. This is a misconception as the word "fine" refers to the number of teeth for each inch of diameter, that is, diametral pitch, not pitch diameter. Fine-pitch gears of six and seven inches in diameter are quite common and it is not at all unusual to find applications which employ such gears having diameters of ten or twelve inches with 32 teeth for each inch of diameter.

The fine-pitch series of gears was arbitrarily set by the manufacturers of gear-cutting equipment as gears of 30 diametral pitch and finer. This article deals with gears in this range of pitch which employ the involute tooth form. Clock and watch gears employ special tooth forms and are not used in devices which require the transmission of uniform angular motion with a minimum amount of backlash. The only highly accurate gears of involute form used in peacetime products were those in motion picture cameras, sound projection equipment, and certain precision instruments. At the time the "defense program" began, the total production was insignificant compared to the huge quantities of gears required for war equipment and there was only a handful of engineers experienced in the design and manufacture of this type of gears. Production machinery capable of turning out fine-pitch gears in large quantities was not available. Today tens of thousands of these gears having as fine as 125 diametral pitch are in use.

Developments in fine-pitch gear-making machinery indicate the degree of accuracy that can be specified by the designer with assurance that the gears can be produced economically on a quantity basis. Because the finished gear cannot be more accurate than the blank from which it is made, it was necessary to have suitable machines and methods for producing accurate blanks. Excello Boring Machines and Heald Borematics are now used extensively to produce blanks that are accurate to a total tolerance of 0.0002 in. on the bore diameter and are square with the faces. Bores as small as 0.125 in. diameter are successfully bored on these machines both in the blank and in the finished gear.

To obtain the greatest possible ac-

curacy in concentricity, some manufacturers top hob the gears and finish bore the hole by locating from the outside diameter of the gear. To keep the clamping stress at a minimum on gears of narrow face width, the gears are reduced in diameter by means of refrigeration usually with CO_2, that is, dry ice. A shrinkage of few ten thousandths inches is usually sufficient. The refrigerated gear is placed in a ring chuck which had been bored in position on the boring machine. Precautions must be taken to keep the blank square with the registration surface of the chuck. The expansion that takes place when the gear warms to room temperature, clamps the blank. Broaching has also played an important part in blank preparation. Spiral broaches suitable for bores as small as 0.125 in. are used in several plants manufacturing these gears.

Foreseeing the trend toward war, the Barber-Colman Company developed and put on the market a Type "S" hobbing machine for making fine-pitch spur gears. This same company also developed the No. 3 precision hobbing machine which incorporated some refinements including a more accurate single-threaded worm and worm wheel. This machine is a decided improvement over the company's standard No. 3 machine which employs a triple-threaded worm and worm wheel.

Improved Machines Developed

Soon afterwards, the Fellows Gear Shaper Company developed two machines for fine-pitch gears. One is essentially the same as the company's No. 7 high-speed gear shaper in that it uses a circular cutter of 1½-in. diameter, and can cut both spur and helical gears. With suitable tooling, it can also be used to produce internal gears. The second machine, known as the Straight Line Generator, is radically different employing a rack-shaped cutter which reciprocates past the work and which is made to cut in both directions of the cutter travel, the cutter slide alternating in direction of travel. Many consider this machine even more versatile than the one employing the circular cutter and claim it is capable of producing more accurate gears. This machine can also be used to produce helical gears, racks and cams.

For the manufacture of fine-pitch bevel gears, including straight, spiral and Zerol types, the Gleason Works made improvements in existing models to meet greater precision requirements. Zerol gears are spiral bevel gears having a spiral angle equal to zero. They can be cut with the same equipment used for cutting spiral-bevel gears. Chief advantages of these gears include the absence of thrust and the ability to introduce a localized tooth bearing in the same manner as that obtained in spiral-bevel gears. They usually replace straight-bevel gears. The localization of tooth bearing is an advantage in that a small amount of misalignment in the mountings can be tolerated without affecting tooth action.

The choice of machines capable of producing this bearing localization is an important factor in obtaining optimum results. Spiral-bevel and Zerol gears usually can be produced more economically and with a greater degree of accuracy than straight bevels.

Many fire control units still employ numerous straight bevel gears which must be extremely accurate. To meet this demand for accuracy, the Gleason Works developed tungsten-carbide shaping tools for fine-pitch non-ferrous straight-bevel gears. These tools have been a boon to the production of these gears. There are instances on record where the tool life was increased in the order of 100 to one over high-speed steel tools with an increase in production output of 100 percent. Increases of 20 and 30 to one are common in the ratios of tool life. Application of these tools, for the present at least, is limited to non-ferrous materials.

The grinding of spiral and Zerol bevel gears of medium pitch out of the solid is an actuality. To date, there are limitations in the ratios which can be handled by the grinding process in the finer pitches. The grinding wheel diameter must be small, hence the spindle must run at extremely high speeds to give the required surface speeds. Research in this connection is progressing steadily and the availability of ground fine-pitch gears in the near future seems certain.

In manufacturing spur and helical gears, the desired accuracy cannot be attained by cutting only; a shaving operation is required. The shaving technique, using various kinds of shaving equipment, had been fairly well developed for the automotive industry prior to the war. The conditions of gear manufacture were more or less similar throughout this industry and it had been empirically determined by the several manufacturers of shaving equipment that a 10 deg. cross axis of the shaving tool relative to the work satisfied the majority of cor litions. Attempts to use these same shaving machines and technique for the fine-pitch gears were unsuccessful. The problem was further complicated by the fact that the more ductile materials such as brass, bronze and particularly aluminum alloys did not respond to the same treatment as did alloy steels.

The Michigan Tool Company and National Broach Company were among the first to produce shaving machines especially suited for fine-pitch gears, and the Fellows Gear Shaper Company soon followed with its No. 4 shaving machine for these gears. It should be pointed out that there are two generally used methods for shaving gears, one employing a rack-type tool made in sections bolted together and the other employing a circular tool. Because of the large number of teeth per inch of diameter the rack-type tool is not considered practical for shaving the fine-pitch gears. It should also be noted that some fine-pitch gears of large diameter are shaved on equipment ordinarily used for coarse-pitch gears. The development of this art has been one of the outstanding contributions to the war effort.

In the fine-pitch field, gears of the following materials are being shaved successfully: 18–8 stainless steel, sintered iron, alloy steels, brass, bronze, aluminum alloys, and zinc. Gears as fine as 100 diametral pitch have been shaved, by far the greater preponderance being between 32 and 64 pitch. Accuracy of 0.00025 in. accumulated error is attainable, that is the total effect of runout, circular pitch and profile error does not exceed this amount. Such an accuracy is greater than that of ground master gears.

Similar remarkable progress, all in less than two years, was made in equipment for the production of precision worm and worm-wheels and worm-wheel segments. Many gears of this type are used in fire control apparatus. Gould and Eberhard and the Barber-Colman Company both developed hobbing machines for the manufacture of extremely accurate worm-wheels. Some manufacturers developed special techniques for shaving worm gears in order to get the last degree of refinement.

Worms of Various Materials

Precision worms are ground from various materials, including bronze, aluminum-bronze, 18–18 stainless steel and sintered iron. Worms made of sintered iron are sometimes impregnated with lubricating oil after they have been ground. The finished worm is immersed in oil and put under a vacuum for a short time to evacuate air in the pores. When the vacuum is released, atmospheric pressures cause the oil to impregnate the gear.

Optical comparators similar to those used for checking threads have been developed for checking the profile on worms. As a result, the modern precision worm-wheel drive is being manufactured to operate with an accumulated error of not more than plus or minus 15 sec. or 1/240 of a degree. Such precision is essential to the dependable operation of fire control apparatus and similar military requirements.

Controlled dimensional accuracy cannot be of an order greater than that of the measuring instruments used for checking. Suitable checking equipment for fine-pitch gears, was not commercially available before the war. The sources for precision-ground master gears were limited and deliveries were prohibitive. Many companies were forced to develop checking equipment of their own. Due chiefly to the lack of suitable checking equipment the pin method of checking gears for tooth thickness was given great impetus. The Van Keuren Company, a pioneer in producing accurately ground pins, developed a set of convenient tables which represent an important contribution. It is not nearly as difficult to obtain master gears today as it was a year or so ago. Several leading broach and gage companies have entered this field.

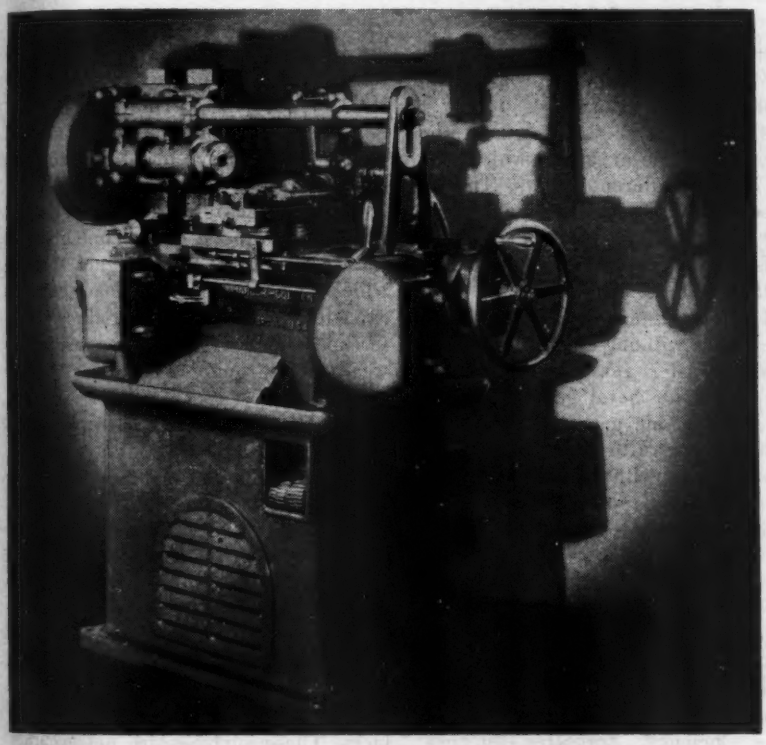
The possibility of shaved master gears made of Nitraloy is definitely in the picture. To circumvent the extended deliveries on master gears, some companies applied the same reasoning and technique in producing so-called "home-made" masters as they did in producing accurately shaved gears. Some of these shaved master gears have been made to a much higher degree of accuracy than ground masters.

An outstanding contribution for the checking of all types of bevel gears up to approximately 4 in. pitch diameter was made by the Gleason Works. The company's "No. 4 Angular Hand Rolling and Power Tester," checks tooth action in bevel gear teeth to an accuracy of 0.0001 inches.

Obviously, it was necessary to adopt recognized standards for fine-pitch gears. For this reason the American Gear Manufacturers' Association in the fall of 1941 established a Fine-Pitch Gear Committee. This committee has already developed three standards:

(1) Clearance for Fine-Pitch Gears
(2) 20 deg. Involute Fine-Pitch System for Spur Gears
(3) System for Fine-Pitch Straight-Bevel Gears

(The A.G.M.A. Standard for 20 deg. Involute Fine-Pitch System for Spur Gears was published in PRODUCT ENGINEERING, Dec., 1943. The Standard for Fine-Pitch Straight-Bevel Gears was published in July, 1944, PRODUCT ENGINEERING). This committee is actively engaged in developing other much needed standards for this field. These standards are aimed to help designers and inventors in adopting up-to-date design practices for fine-pitch gears of all descriptions.



Refinements in this Barber-Colman No. 3 Precision Hobbing Machine include a more accurate single-threaded worm and wormwheel.

Naturally a great many misconceptions exist concerning the accuracy that can be expected of commercially available fine-pitch gears, the tooth forms used and the basic dimensional accuracies that can be expected in these "out-of-stock" gears. Unfortunately, it is not generally recognized that conventional commercial gears and precision fine-pitch gears differ considerably. About the only thing these two classes of gears have in common is that both use the involute tooth form.

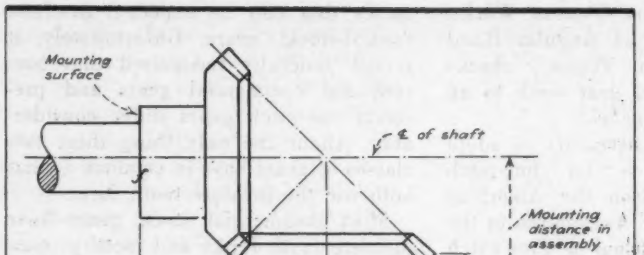
Most commercial stock gears have obsolete tooth forms and tooth proportions. The 14½ deg. pressure angle is extensively used in gears of this type whereas the higher pressure angle, 20 deg., and tooth proportions sponsored by the A.G.M.A. offer advantages not obtainable with gears of other systems. As the advantages of these gears became recognized their application was broadened and many new designs have incorporated gears made in accordance with the A.G.M.A. standards.

Incidentally, some designers have placed too much emphasis on the relation of pressure angle to center distance variation. It is true that the smaller pressure angle is less sensitive to variations in center distance, but it is no longer difficult to maintain accurate center distances. Hence this argument no longer applies.

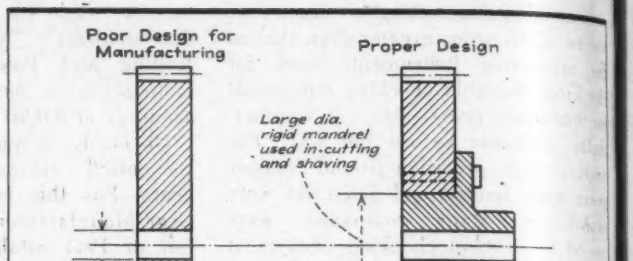
Errors in Early Designs

Many of the errors in the early designs involving fine-pitch accurate gearing could be traced to the use of commercial gears in pilot models. By various expedients it was possible to make such models work satisfactorily but when the designs were put into production it often was found impossible to manufacture them satisfactorily. The commercial gears used in pilot models invariably had obsolete tooth proportions and pressure angles, their run out and profile error was excessive, and often they could not be made to operate without backlash and with uniform angular motion. The expedients used in the tool room in making the pilot model did not permit interchangeable manufacture as required for mass production.

In scanning the fine-pitch gear field for some of the many misconceptions which exist, one finds many inconsistencies in design. These often emanate from institutions engaged in developing new inventions using these gears and from companies which have not specialized in precision gear work. As an example, one drawing called for a gear 5½ in. in diameter with a hole having a taper of 1¼ in. per ft. The length of the bore was $\frac{7}{8}$ in. and the large end of the bore was dimensional as being $\frac{7}{16}$ in. All the dimensions were specified in fractions, including the taper. This gear, however, specified a close tolerance for pitch diameter and a run out of 0.0005 in. total indicator reading. The inconsistency was a note on the


Mounting surface
℄ of shaft
Mounting distance in assembly
Mounting surface
Crown-to-back distance, held to close tolerance in manufacture of gear
Mounting distance in assembly
℄ of shaft

It is easy to mount bevel gears accurately if their crown-to-back distance is made to close limits. When the gears are then assembled to correct mounting distance they will mesh properly. It is not necessary for the back cones to come flush.


Poor Design for Manufacturing
Proper Design
Large dia. rigid mandrel used in cutting and shaving
Arbor or mandrel so small it deflects during cutting and shaving. Hence inaccuracies
Shrink or press fit
Could be held by screws or rivets

Manufacturing difficulties will be encountered if the bore is small in relation to pitch diameter. The bushed hub illustrated permits use of large diameter rigid arbor in manufacturing operations, hence greater accuracy in production.

drawing "± $\frac{1}{64}$ in. allowable on all fractional dimensions."

Another drawing of a similarly accurate gear having a 6 in. diameter called for a $\frac{1}{8}$ in. diameter hole, $\frac{1}{4}$ in. long. The designer could have used a considerably larger bore, of the order of $\frac{3}{8}$ in. or $\frac{1}{2}$ in. and inserted a hub, as illustrated. For the accuracy specified, shaving of this gear was unquestionably indicated. Disproportionality of bores to outside diameters is a common offense by some designers.

Involute Gears Preferred

Some gears were designed with clock-gear tooth forms which were copied from gears used in foreign instruments. These tooth forms are modified cycloidals that require a different hob or cutter for each different number of teeth and each different pitch. Such gears do not lend themselves readily to generating methods as do gears of involute form. Furthermore ground hobs and generating tools are not generally available. In most cases where gears of this type have been specified, involute gears would have done the job cheaper and better with savings in tools.

Another typical misconception of gear design and cutting practices is found in the many drawings that specify a gear to match with a mating gear to be made by another manufacturer. It is virtually impossible to cut precision gears in one factory and have them run properly in mesh with precision gears made at another plant. The one plant might produce the gears by the hobbing process while the other may use a shaping process. Unless "exact pressure angle" is specified in the shaped gear it may not mesh properly with the hobbed gear. Even when all the facts are known there is usually enough difference in gear cutting equipment and techniques in two different plants to produce the highest degree of accuracy.

This condition is far worse in the production of bevel gears which are made in two different plants. This is because tooth bearing can be altered readily and that, in practice, a bevel gear is cut to match its mate or an accurate facsimile. There is no absolute way of measuring all of the elements of a bevel gear without engaging it with its mate. Master gears, as such, are not available for bevel gears. For this reason, responsible gear manufacturers will not undertake to cut one of a pair of bevel gears without its mate and by the same token, replacements of bevel gears in mechanisms should always be made in matched pairs.

In designing both spur and bevel gears, some designers fail or refuse to specify enlarged pinions that will avoid undercutting the teeth. They contend that enlarging the pinion causes greater sliding and hence less durability and efficiency. Actually, efficiency and durability are increased due to the elimination of undercut. While the enlarged pinion has greater sliding velocity, this has never been proved to be a detrimental factor.

Perhaps the worst mistakes are made in the specifications of straight and spiral bevel gears. Apparently many designers are unable to figure the tooth forms and summaries for spiral-bevel gears and some still labor under the impression that satisfactory bevel gears can be produced by milling. This is far from being true. Fine-pitch spiral-bevel gears are cut by the duplex spread blade method and such elements as spiral angle, tooth proportions and pressure angle are intimately tied up with the method of production. Each case must be calculated separately by engineers capable of developing summaries for these gears. With regard to milled straight bevel gears, the best that can be hoped for under the best conditions is a fair approximation of the true generated straight bevel gear.

One finds gears of this type specified with face widths $\frac{1}{2}$ of the cone distance. It is assumed by the designer that the wider face adds to the load carrying capacity. Actually this introduces interference which results in a weaker instead of a stronger tooth.

Dimensioning Blanks

Another common error in the design of precision bevel gears is found in the dimensioning of the blank. Often the dimensioning indicates that the teeth are to be cut registering from one surface and mounted registering from another surface. And it is not uncommon for designers to specify that the mating bevel gears are to be positioned on the shaft by matching the back cone surfaces. These surfaces are not accurate, nor is there any reason for them to be so. The back faces of the hub, or some similar registration surface as shown in the accompanying illustration, are the surfaces that are accurate with respect to the apex of the pitch cones and that should position the gears.

To people versed in the art of gearing some of these things seem ludicrous and far fetched. This is far from the case and serves only to emphasize the argument of the many misconceptions that exist in the fine-pitch gear field. One customer for instance, insisted that the root angle in certain straight bevel gears be held to the drawing. In the first place, these gears were cut to obsolete tooth proportions and were mounted on shafts away from any positive registration surface in such a manner that the

only way proper mesh could be obtained was to slide one of the gears on the shaft until their back cones lined up. Secondly, to eliminate a slight amount of run out the gears were lapped in the assembly. Due to the lapping operation the teeth became thinner. Inasmuch as the gears were required to operate metal to metal they were again brought in intimate contact after the lapping operation by bringing the back cones slightly out of flush. When this was done the teeth bottomed in some cases. It was specified as not permissible on this job to change face angles or root angles to provide the additional clearance necessary, yet that was the only way it could be done. Much valuable time and money was wasted because of poor design and much poorer judgment. The root angle in bevel gears controls clearance and should not be considered as an iron-clad element that cannot be varied to suit conditions.

Many bevel gears are still designed with equal addendum proportions for both gear and pinion. This is incorrect except for miter gears. In all other bevel gears where the pinion teeth are undercut they should have long addenda and the gear teeth short addenda. The same principle applies to spur gears and is the main reason for preferring the 20-deg. full depth involute system over the 14½-deg. pressure angle. With the latter, the smallest spur gear that can be generated without undercut is 32 teeth. With the 20-deg. system the smallest spur pinion producible without undercut is 18 teeth. Spur gears with less than 18 teeth have long addenda to avoid undercut.

Mention was made above of bevel gears being lapped together in assembly. It cannot be emphasized too strongly that this is poor practice. Bad gears cannot be improved by lapping together. This practice is fraught with danger and many gear failures can be traced to cases where gears were lapped together and where often one or both of the gears became charged with abrasive, thereby becoming in effect a permanent lap. Only if done on a special machine under controlled conditions will lapping improve the gears. Merely running a pair of gears together with fine abrasives in an attempt to lap out defects creates other inaccuracies. Nor does lapping overcome errors in the gear mountings.

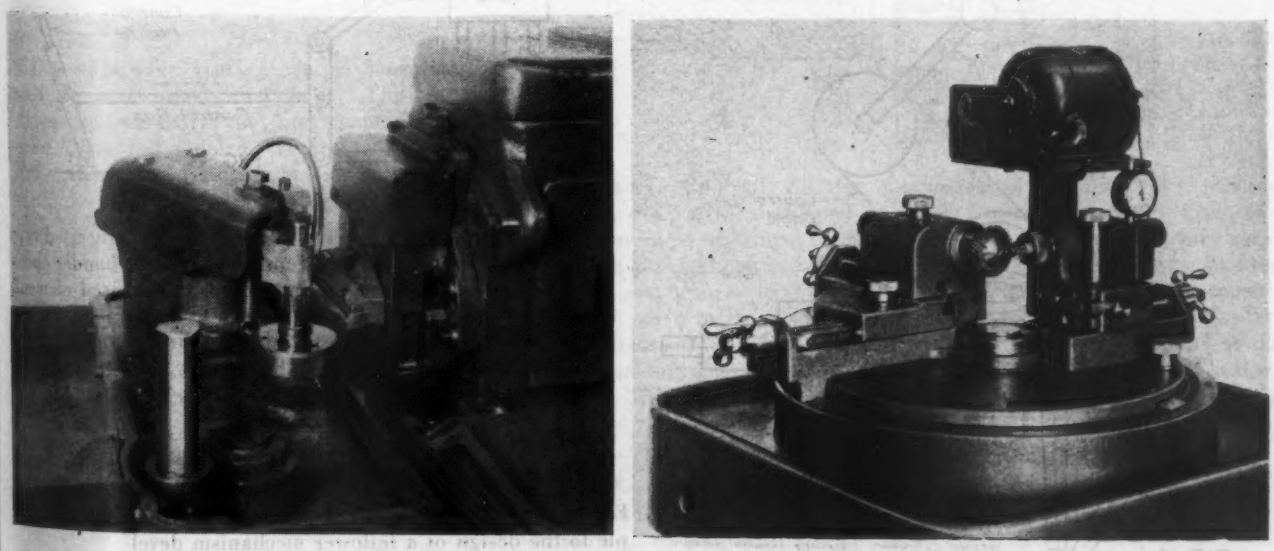
Mountings Are Important

Only too often gears are blamed for poor mountings and incorrect center distances. Volumes could be written on this one subject. It seems silly to specify close tolerances on gears without consistently doing likewise on the gear centers and mountings. This applies to all types of gear mountings and is particularly critical where relatively high speeds are required. Shafts must be rigid enough to avoid deflection under load. Adequate thrust provisions must be made for helical and spiral bevel gears and accuracy in the mountings should be compatible with the performance expectation of a gear train.

Sleeve or pivot bearings may be indicated in preference to ball bearings in certain applications where precision is most important. When the gears are mounted on ball bearings the run out of the bearings themselves may often affect the accuracy of the gear by introducing additional run out. To overcome this, some manufacturers have found it necessary to shave these gears with the ball race mounted in place, taking suitable precautions against dirt and chips. The ball bearing is usually fitted snugly in the gear bore and staked in position to prevent any subsequent rotation of the outer race in the bore.

Much of the fire control equipment employ gear trains which have to operate with little or no backlash and also meet rigid torque requirements. The temperature range in which these instruments operate may be wide, often considerably more than 120 deg. F. The selection of materials for the gears themselves, the gear case and other components so that the thermal expansion is uniform, is an important consideration. Much trouble has been experienced by some manufacturers because gears which meshed with each other were made of dissimilar materials which had different coefficient of expansion. In some instances the gear frame or housing was made of still another material. When assembled at room temperature the instruments worked satisfactorily but it was another story when they were subjected to the wide range of temperatures encountered in service.

The experiences gained in this war will undoubtedly lead to a far wider use of precision fine-pitch gears. Development of such gears for fire control apparatus, radar, shell fuses and similar equipment has established new criteria of perfection. Many postwar products will be forced by the very nature of progress to adopt precision gears where gears of commercial quality had been used. The price differential between these two classes of gears has been greatly decreased by the wartime developments. The small added cost of silent and smooth-operating precision gears will be more than offset by the increased customer satisfaction in having a more efficient and durable product.



(Left) Rack-type cutter is used on the Fellows Straight-Line Gear Generator set-up to cut spur gears. (Right) Bevel and spur gears up to 4-in. dia. can be checked on the No. 4 Angular Hand Rolling and Power Tester of the Gleason Works.

VALVE FOLLOWER MECHANISMS

ANY power-operated positioning mechanism, wherein the power controlled element is caused to move to a position corresponding to that to which the manually-operated control lever or wheel has been shifted, must incorporate a valve follower mechanism. The purpose of the valve follower mechanism is to automatically return the control valve of the power or servo unit to its neutral position when the controlled element reaches the position corresponding to that to which the control lever has been shifted.

Mechanical follower mechanisms are of one of the following basic types: (1) Screw and nut, (2) wedges, (3) floating levers, (4) epicyclic gearing, (5) flexible cord and pulleys. Electrical and electronic circuits and devices are also possibilities that might be considered for certain applications.

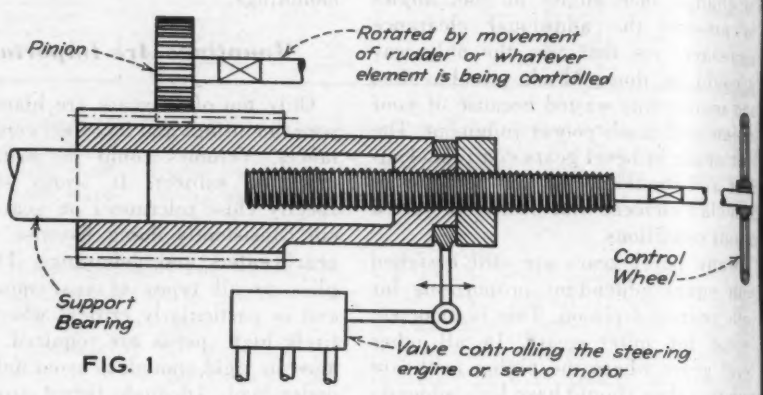

Pinion
Rotated by movement of rudder or whatever element is being controlled
Control Wheel
Support Bearing
Valve controlling the steering engine or servo motor
FIG. 1

Fig. 1—Schematic of screw-and-nut follower mechanism. Rotation of control wheel by the operator causes axial movement of the nut in one direction, thereby actuating the valve controlling the servo motor. Servo motor moves the rudder, motion of which causes rotation of pinion in such a direction as to cause opposite axial travel of the nut, thereby returning the valve to neutral position. This is an old mechanism used for steering ships. The servo motor can be a steam engine, hydraulic or pneumatic cylinder or engine or an electric motor. For the last type, the valve is replaced by an electric control switch.

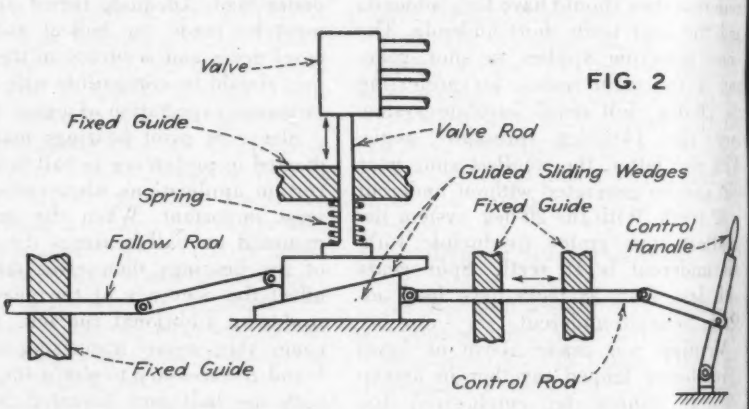


FIG. 2

Fig. 2—A screw thread can be thought of as a modified inclined plane. Moving the control handle displaces the valve from its neutral position, causing servo motor to move the element being controlled. This last movement causes the follow rod to move in the same direction in which the control rod was moved, thereby returning valve to its neutral position.

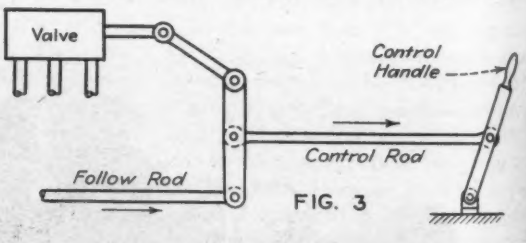


FIG. 3

Fig. 3—The floating lever is the most commonly used type of follower mechanism. Movement of control handle opens valve, causing servo motor to operate the desired element, movement of which causes follow rod to move in same direction as movement of control rod. This brings valve back to neutral position.

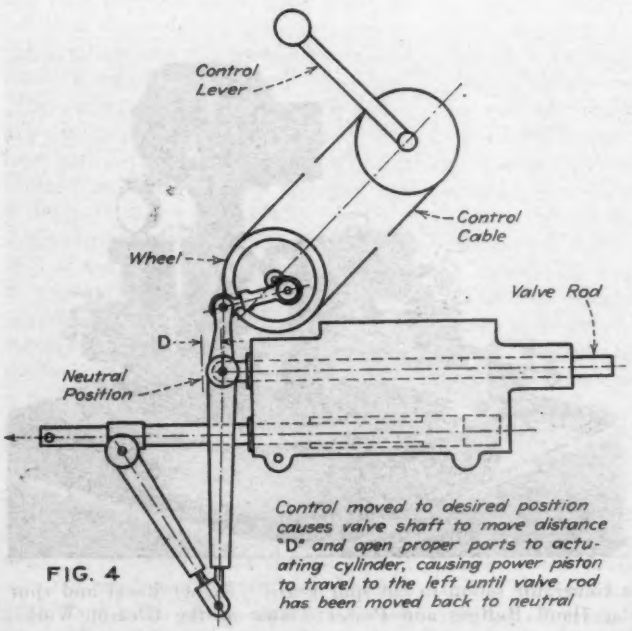

Control Lever
Control Cable
Wheel
Valve Rod
D
Neutral Position
Control moved to desired position causes valve shaft to move distance "D" and open proper ports to actuating cylinder, causing power piston to travel to the left until valve rod has been moved back to neutral
FIG. 4

Fig. 4—Application of the floating lever principle to the design of a follower mechanism developed by Curtiss-Wright Aircraft Corporation. The valve and servo power cylinder are a unit.

FOR SERVO CONTROLS

Fig. 5—Modified form of floating lever principle applied to another Curtiss-Wright design. One advantage is the compact design made possible.

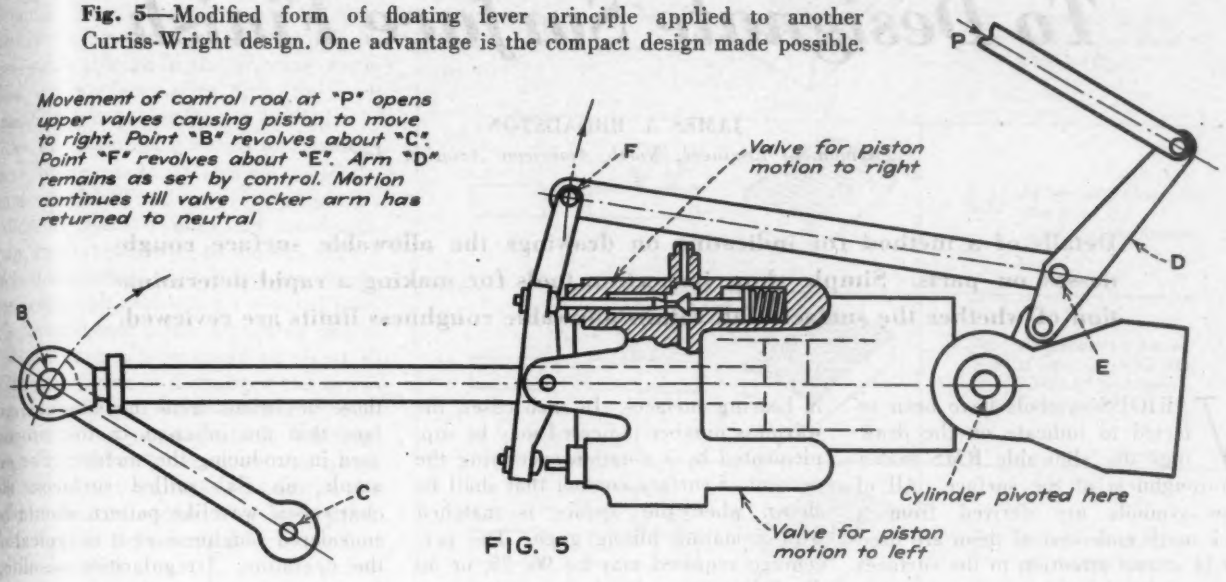

Movement of control rod at "P" opens upper valves causing piston to move to right. Point "B" revolves about "C". Point "F" revolves about "E". Arm "D" remains as set by control. Motion continues till valve rocker arm has returned to neutral
P
F
Valve for piston motion to right
D
B
E
C
Cylinder pivoted here
Valve for piston motion to left

FIG. 5

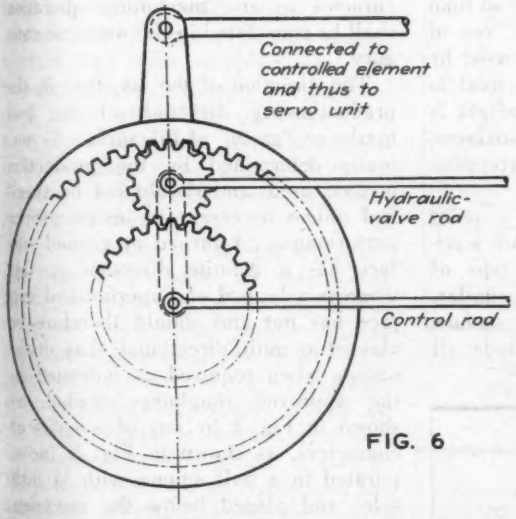


FIG. 6

Fig. 6—Epicyclic gearing can be considered a modified form of floating lever. This merely shows schematically the arrangement of the gears. The rod labeled "Hydraulic-valve rod" can actuate an electric rheostat or switch, pneumatic control valve, or any other device for the control of a power unit.

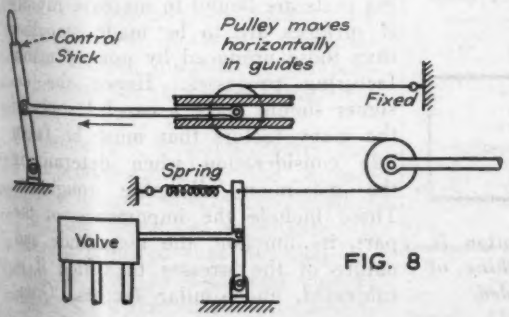


FIG. 8

Fig. 8—Flexible metal tape running over pulleys can be used for follower mechanisms. This type mechanism is specially suited where a greater number of movements are involved as it is merely necessary to increase the number of pulleys.

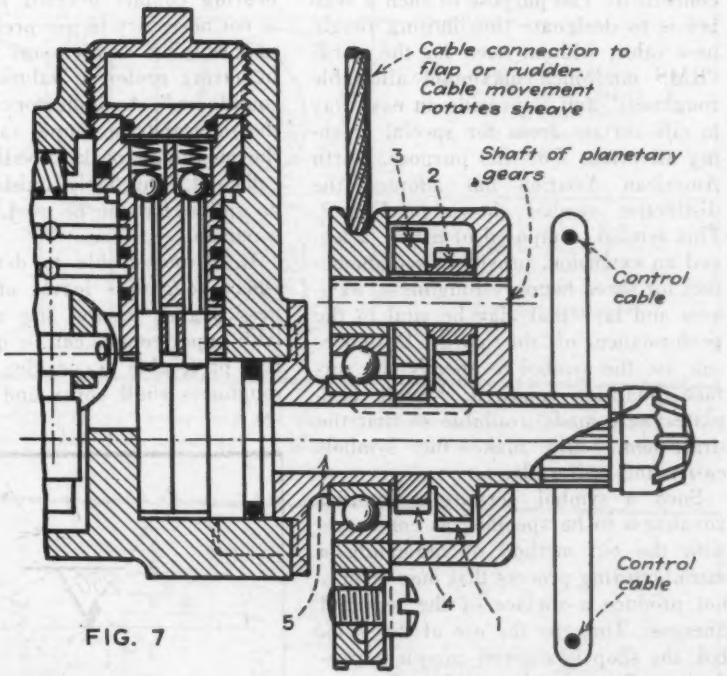


FIG. 7

Fig. 7—Epicyclic follower mechanism is built into this "position control valve" developed by Adel Precision Products Company. Movement of control cable rotates gear *1*. Shaft of planetary gears remains stationary, hence angular rotation of gear *1* is transmitted to gear 4 keyed to valve shaft, thus operating the valve and causing the servo to move the flap, rudder or whatever the part may be. Movement of flap rotates the sheave and with it, the shafts of the planetary gears. Gear *1* remains stationary and planetaries roll on it. This causes rotation of valve shaft back to its neutral position.

Distinctive Symbol Adopted To Designate Surface Finish

JAMES A. BROADSTON
Armament Engineer, North American Aviation, Inc.

Details of a method for indicating on drawings the allowable surface roughnesses on parts. Simple shop inspection tools for making a rapid determination of whether the surfaces fall within allowable roughness limits are reviewed.

VARIOUS symbols have been selected to indicate on the drawings the allowable RMS microinch roughness of the surface. All of these symbols are derived from a check mark and most of them are used only to attract attention to the surfaces that are critical insofar as roughness is concerned. The purpose of such a symbol is to designate the limiting roughness value, without need for the words "RMS microinch maximum allowable roughness" and to provide an easy way to cite certain areas for special finishing attention. For this purpose, North American Aviation has adopted the distinctive symbol shown in Fig. 1. This symbol, composed of a flag, a leg, and an extension, provides accommodation for three factors—roughness, waviness and lay—that may be vital to the performance of the part. Designers can use the symbol to specify the surface qualities required. Small templates were made available so that the draftsmen could make the symbols easily and uniformly.

Such a symbol permits a limiting roughness to be specified as contrasted with the old method of indicating a manufacturing process that may or may not produce a surface of the required fineness. Thus, by the use of this symbol, the shop is allowed complete freedom to select what it considers the most suitable process for manufacturing, the only restriction being that the final finish shall fall within the roughness limit specified on the drawing. Although the waviness of a surface is not always specified, being indicated only when it is of significance, as in bearing surfaces, the symbol provides for its specification. The number entered on the symbol in the location shown in Fig. 2, is the maximum allowable waviness as determined by actual measured distances from the crests to the valleys of the waves. Waviness designation is of importance only when it is desired to control the percentage of contact area, as in bearing surfaces. In such cases, the waviness number indicated may be supplemented by a notation specifying the percent of surface contact that shall be shown when the surface is matched with a mating bluing gage. The percentage required may be 90, 75, or 50 depending upon the degree of intimate bearing contact deemed necessary. It is not necessary to use preferred values in specifying waviness any more so than in having preferred values for "out of roundness." As indicators are used by the thousands, a simple value equal to the maximum peak to valley height is sufficient. On finely finished surfaces, an optical flat can be used to determine waviness.

It is undesirable to define a point where roughness leaves off and waviness begins, as the size and type of both imperfections can be quite similar. It is preferable to consider that surface roughness shall cover and include all those deviations from the nominal surface that are inherent in the process used in producing the surface. For example, on slab milled surfaces, the charteristic wavelike pattern should be considered roughness as it is typical of the operation. Irregularities resulting from causes such as geometric imperfections of the machine, or deflections, vibration and other sources of inaccuracies in the machining operation shall be considered in the waviness category.

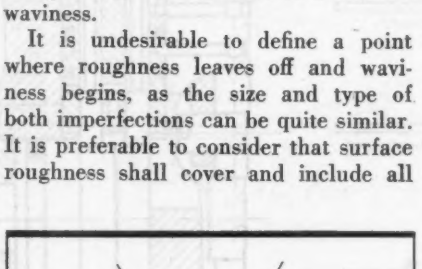


Fig. 1—Distinctive symbol adopted by North American Aviation, Inc., for use on drawings to define the surface qualities required.

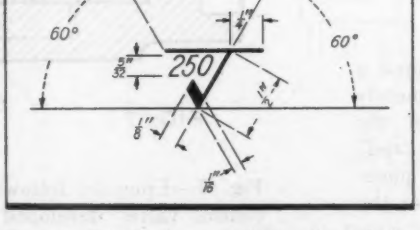


Fig. 2—A place for lay designation is included to simplify the furnishing of that information when it is needed.

The direction of the lay, that is, the predominating direction of the tool marks or "grain" of the surface is normally determined by the production method used, and should not be specified unless necessary to insure proper performance. A turned or ground surface has a definite direction or lay, whereas a lapped or Superfinished surface has not and should therefore be classed as multi-directional. Lay designation, when required, is indicated on the approved roughness symbol, as shown in Fig. 2 by one of a series of characters, as shown in Fig. 3, incorporated in a half square with ¼ inch sides and placed below the extension line and opposite the flag. Fig. 4 illustrates the approved and typical methods for applying the roughness symbol to the drawing, and how certain areas can be designated for special care.

In selecting the roughness number to be placed on the symbol to indicate the required surface finish on a part, it should be recognized that manufacturing costs are bound to increase rapidly if surfaces are to be made smoother than those produced by normal manufacturing processes. Hence the designer should make a careful study of the many factors that must be taken into consideration when determining the maximum allowable roughness. These include the importance of the part, its function, the magnitude and nature of the stresses to which it is subjected, and similar factors. Occa-

sionally, the draftsman may specify a surface roughness that is needlessly fine. As the success of any system of surface roughness designation is largely dependent upon its proper use, the shop will be doing everyone a favor if it insists on a change in the drawing whenever an unnecessarily fine finish is specified but obviously not needed.

As an example, a series of bushings were being made of chrome molybdenum steel. The drawing originally called for reamed holes and the draftsman, in changing over to the new microinch designation, looked up the roughness range allowable for a reamed hole. He decided that a fair allowable roughness for such a hole would be about 40 RMS microinch and changed the drawing accordingly. A sub-contractor, who had been making acceptable bushings for a long time, delivered a large quantity and they were rejected because the holes were too rough, that is rougher than the 40 microinch RMS specified on the drawing.

Investigation revealed that the bushings were pressed into a magnesium casting to distribute heavy bearing loads from a bolt. The inside surface finish was not at all critical. The only reason a ream had been specified was that reaming easily produced accurately sized holes within the drawing tolerance. Accordingly the allowable microinch roughness was increased by a drawing change and everything was satisfactory thereafter.

It is not sufficient that the engineering department have an established means for specifying allowable surface roughness and surface qualities on the drawings. There must also be available a method for making surface roughness determinations quickly and readily by the shop inspector to make certain that the roughness of each critical surface of the parts produced does not exceed the maximum allowable roughness specified. Unfortunately, the tracer point analyzers now available for measuring surface roughness, namely the Brush Analyzer and the Profilometer, are not entirely suitable for general use as shop inspection tools for quantity production. They are delicate instruments, must be handled carefully, and are quite expensive. These instruments are primarily laboratory instruments for the measurement of surface roughness and for making quantitative comparisons between the roughness of different surfaces.

Fortunately, it is not necessary that the inspectors measure the surface roughness in order to determine whether or not the finish is acceptable. It is merely required that the shop inspector be able to determine quickly whether or not the surface produced is

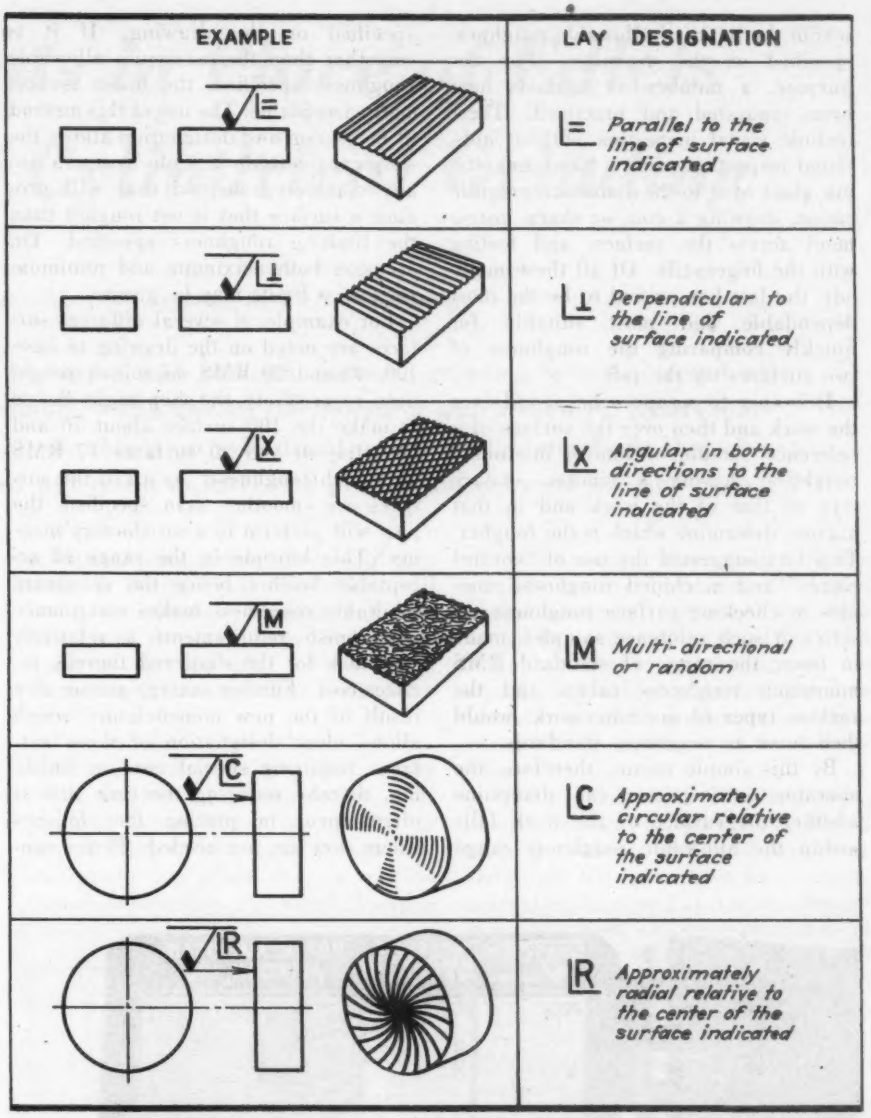

EXAMPLE
LAY DESIGNATION
= Parallel to the line of surface indicated
⊥ Perpendicular to the line of surface indicated
X Angular in both directions to the line of surface indicated
M Multi-directional or random
C Approximately circular relative to the center of the surface indicated
R Approximately radial relative to the center of the surface indicated

Fig. 3—Symbols for indicating the lay or predominating direction of the tool marks. Lay need not be designated except in special cases.

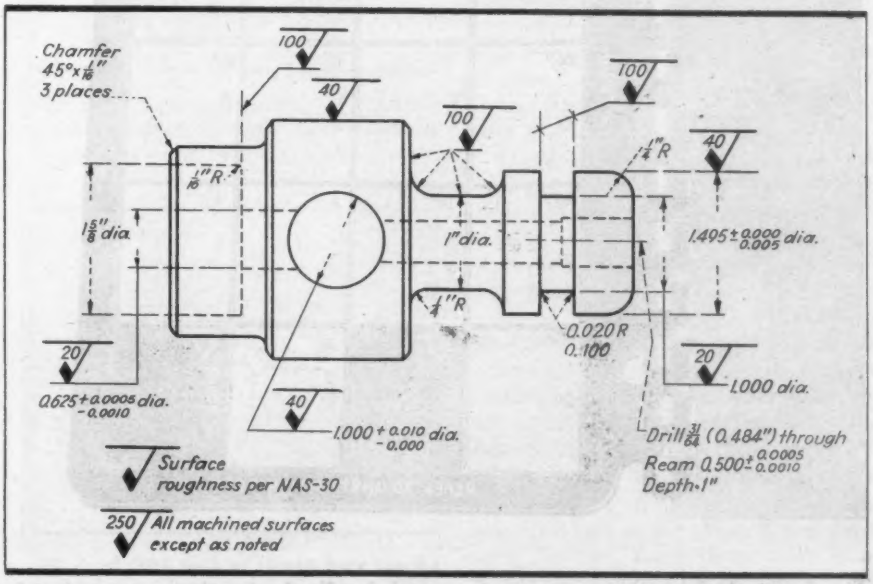


Fig. 4—Typical methods are shown for applying the roughness symbol to a drawing. Certain areas are designated for special care.

within the limits of allowable roughness specified on the drawings. For this purpose, a number of methods have been suggested and practiced. These include visual inspection without aids, visual inspection using a hand magnifying glass of 5 to 20 diameters magnification, drawing a coin or sharp instrument across the surface, and feeling with the fingernails. Of all these methods, the last has proved to be the most dependable and most suitable for quickly comparing the roughness of two surfaces on the job.

It is easy to scrape a fingernail over the work and then over the surface of a reference sample of known microinch roughness having a similar surface type to that of the work and in that manner determine which is the rougher. This fact suggested the use of "control pieces" and machined roughness samples in checking surface roughness. A series of such reference samples, made to cover the range of standard RMS microinch roughness values and the various types of machine work, would then serve as roughness standards.

By this simple means, therefore, the operator or inspector can determine whether the surface of the work falls within the allowable roughness range specified on the drawing. If it is smoother than the maximum allowable roughness specified, the finish is normally acceptable. The use of this method of inspection and designation allows the shop considerable latitude as it can use any machining method that will produce a surface that is not rougher than the limiting roughness specified. On occasion both maximum and minimum roughness limits may be given.

For example, if several different surfaces are noted on the drawing to have 100, 40 and 20 RMS microinch roughness, respectively, the shop might choose to make the 100 surface about 70 and both the 40 and 20 surfaces 17 RMS microinch roughness. As all of the surfaces are smoother than specified, the part will perform in a satisfactory manner. This latitude in the range of acceptable finishes below the maximum allowable roughness makes compliance with finish requirements a relatively easy task for the shop and thereby reduces cost. Further savings accrue as a result of the new nomenclature which allows clear designation of those surfaces requiring special care in finishing, thereby reducing the time that is often spent in putting fine finishes where they are not needed. Better control of both of these factors reduces considerably the need for handwork prior to assembly.

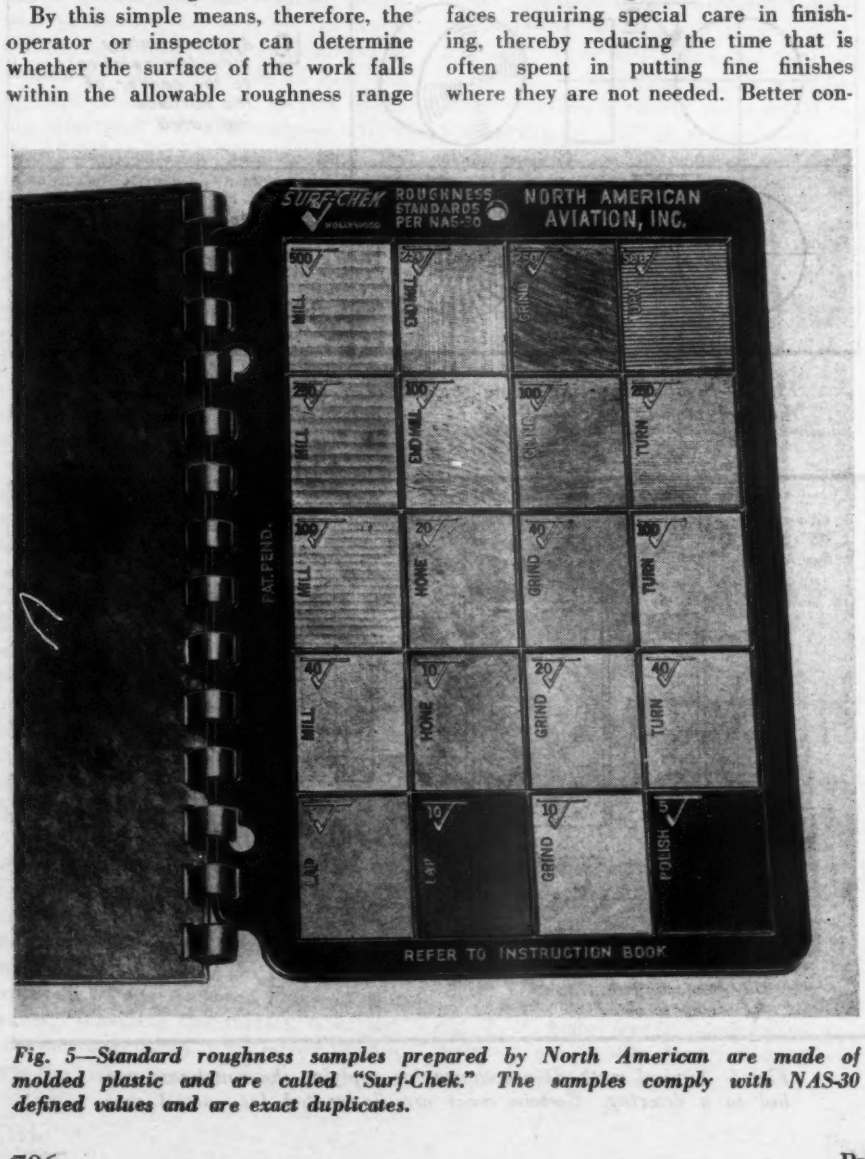


Fig. 5—Standard roughness samples prepared by North American are made of molded plastic and are called "Surf-Chek." The samples comply with NAS-30 defined values and are exact duplicates.

Obviously the difficulty in establishing the "roughness comparison" method of inspection described lies in the expense and difficulty of making large quantities of "standard" roughness specimen sets for tactual comparison. It is not easy to produce surfaces to definite specified RMS microinch roughnesses. It is quite difficult to machine a specimen with a certain tool, and then machine another one, using the same tool and have it come out with the same identical roughness. During cutting action there is a tendency for chips to adhere to the cutting edge of the tool and cause a change in the roughness of the finished surface. Variables of this sort, that cannot be controlled, will cause a considerable and measurable variation in the roughness between areas of even one specimen. In grinding specimens a similar variation between "standard" specimens is caused by wheel wear.

The preparation of a large number of practically identical specimens for distribution to all who are concerned with surface roughness control can best be accomplished by some method whereby accurate replicas can be produced.

At North American Aviation this problem was solved in a relatively simple manner. A complete set of standard surfaces was made with extreme care. By using precise measuring methods to be described in a later article, samples were produced to roughness numbers conforming to the NAS-30 standard.

These sample surfaces were made of a high quality tool steel, and after being checked for accuracy by the method of taper sectioning, were "hobbed" into mild Swedish steel (Rema iron) blocks. After these relatively soft blocks, each having a reversed or negative impression of the standard surface were engraved with the proper designation and machined to fit into a plastic pressure molding cavity, they were case hardened under a controlled atmosphere and inserted in the mold.

Hard bakelite plastic castings were then made in the mold that duplicated the original surfaces to an unbelievably accurate degree, and provided standard roughness samples that could be easily duplicated in large quantities without loss of the original "master" machined and hardened surfaces. These molded plastic "Surf-Chek" Roughness Standards, shown in Fig. 5, comply with the NAS-30 defined values and are exact duplicates. They can be produced in sufficient quantity to supply identical samples to all who need them in controlling the surface quality of manufactured parts.

Undercuts in Place of Fillets Simplify Cylindrical Grinding

S. H. NEADY
Assistant Chief Engineer, Landis Tool Company

Considerations dictated by stress and strength factors, grinding practice requirements and equipment available, which govern the design of sharp corners, reliefs and fillets at inside corners of shoulders on cylindrical parts. Design standards that observe the factors discussed will result in increased production and reduced shop costs.

WHEN designing a part which is to be finished by grinding and which has a shape that necessitates a relief, fillet, or sharp corner at a shoulder or stepped diameter, three practical rules should be kept in mind:

1. Sharp corners should be avoided wherever it is possible to do so.
2. Reliefs should be used when strength requirements permit.
3. Fillets should be designed to facilitate grinding operations.

There is seldom any compelling reason for specifying a sharp corner. From the design point of view sharp corners are undesirable because under repetitive stress they may become starting points for cracks which may develop into fatigue fractures. In the shop, pieces having sharp corners are nuisances for it is impossible to retain a sharp corner on a wheel without frequent truing.

The best way to grind a diameter and an adjoining shoulder in one operation is with the grinding head set at an angle, usually 30 or 45 deg., but such machines are not always available. When a plain cylindrical grinder is used the best method is to grind the face of the shoulder first while feeding the wheel into the corner. Either a straight or a dished wheel can be used, as shown in Fig. 1. By this method the wheel wear, and consequently the amount of truing, will be kept at a minimum. The criss-cross pattern left on the face of the shoulder may be undesirable if the surface is to be used for a thrust bearing. Grinding with the wheel at an angle does not have this effect since the pattern will consist of concentric circles.

The most expensive procedure, which is used far too often, is to start the cut on the part at the end opposite the shoulder, then traverse the wheel to the shoulder. Even though the first part of the operation is done with power traverse, hand traverse must take over as the wheel approaches the shoulder, resulting in slow grinding. Even with care there is danger that the wheel will bump the shoulder, ruining both the wheel and the work. Also, in traverse work the leading edge of the wheel wears rapidly since it does most of the grinding.

To avoid these production difficulties, if a diameter and adjoining shoulder are to be ground in one operation, their junction should either be relieved or have a fillet. On the basis of both cost and production in the shop, a relieved corner is desirable. No wheel truing is necessary except when needed by the straight cutting face. Correct cutting characteristics of the wheel are maintained by normal dressing. If the cylindrical surface is traverse-ground the corner of the wheel will wear, of course, but no matter how much it breaks down there will be no effect on the relieved corner.

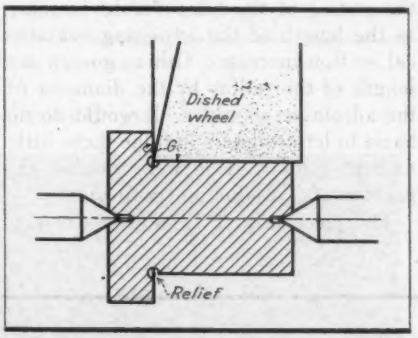


Fig. 1—Method of grinding a diameter and an adjoining shoulder using a straight or a dished wheel in one machine setting.

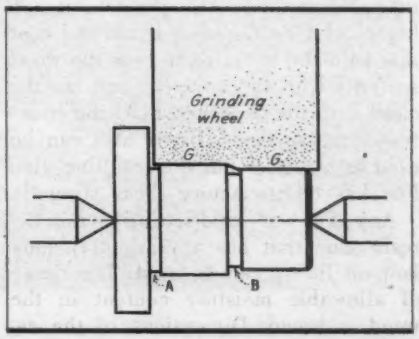


Fig. 2—A part such as shown here can be ground by plunge-cutting with a wide-faced wheel if the junctions at stepped diameters are relieved at points A and B.

With a wide wheel available, grinding should be done by plunge-cut, Fig. 2, then the wheel edge will not wear. Originally the part shown was designed with fillets at *A* and at *B* where the two diameters meet. The designer had specified two fillets of different radii, hence two operations were required, each with a different wheel. The alternative was to run the lot through once for the shoulder fillet, and then again for the one in the middle.

An investigation revealed that there was no reason for having fillets. Because of the extremely low stresses involved, some degree of stress concentration would be permissible. So the part was redesigned as shown with reliefs taking the place of fillets. The job could then be done by wide-wheel plunge-cut, in less than half the time needed for the part as originally designed.

Experience shows that when reliefs supplant fillets in the design of a part, rate of production of small parts will at least double, and production of large parts will increase at least one-third. The increase results from both faster grinding and reduced truing time. If the shoulder need not be ground, it is usually possible to do away with all hand feed. A power feed can be used which is set to stop as soon as the advancing edge of the wheel overlaps the relief.

Usually the designer specifies that a fillet shall be ground even though the shoulder face is not. That means hand feed. Further, many times there is no reason for grinding the fillet. When this is true, time will be saved if the designer will indicate precisely how close to the

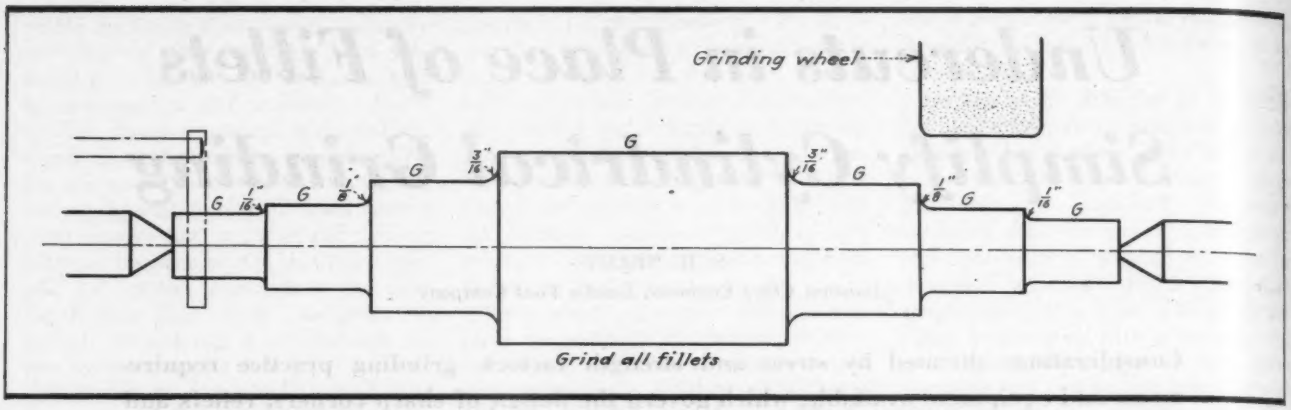


Fig. 3—To grind this part, which has six fillets of three different radii, six wheel truings were required.

shoulder the grinding must go. Much time is used grinding surfaces that do not need to be ground. When it is possible to grind nearly up to a fillet on a forged or cast piece without grinding the fillet the cost will usually be reduced, because a relieving operation, which usually means one entire setup, is not needed.

In recent years, the trend of design has been toward fillets and away from reliefs because of the emphasis on avoiding stress concentration and obtaining maximum strength, especially in airplane design. As usual, the pendulum has swung too far, and now fillets are used on many parts where reliefs or undercuts at corners would be as good from a design point of view and better from the shop standpoint.

One reason for the high cost of fillets is the need for truing the wheel corner frequently. It is necessary to true a corner of small radius more often than one of large radius because the small one breaks down more rapidly. It is desirable, therefore, to keep the fillet radii as large as possible.

It is essential that a radius "blend" smoothly into the adjoining surfaces to prevent the formation of fatigue cracks. Some designers have the idea that a small radius is easiest to blend, but to get a good blend it is necessary to make the straight surfaces tangent to the curve, which is not an easy operation.

The most common and least excusable design fault with regard to fillets is to specify several different radii for the various fillets. There seems to be no sound engineering principle behind this. It is only the designer's idea of what is suitable. Some think that to be artistic the radius of the fillet should increase as the length of the adjoining cylindrical section increases. Others govern the length of the radius by the diameter of the adjoining shoulder. It would do no harm to let designers indulge these little artistic foibles, if it were not so expensive and production retarding.

The piece, Fig. 3, is shown as originally designed, it had six fillets of three different radii. To grind this piece necessitated that the wheel be trued on both edges to $\frac{1}{16}$ in. radius, then re-trued on both edges to $\frac{1}{8}$ in. radius and finally to $\frac{3}{16}$ in. A total of six truings per piece. Finally, to get reasonable production of this badly needed part, permission was secured from the engineering department to make all of the fillets with a $\frac{1}{8}$ in. radius. This saved four truing operations. The production time was halved and the part worked as well in its assembly as the more complicated one had.

It would undoubtedly pay most shops which do their own designing to standardize the design practice governing inside corners. This should be done after a consultation between the shop and the designing department that would consider not only the unalterable requirements of strength and weight, but also the available grinding equipment. Such standardization should result in increased production and reduced cost.

A New Hot-Gluing Technique

DEVELOPMENT OF A NEW TECHNIQUE for gluing laminated wood, plastics, cloth and plywood was described by Dr. W. Gallway, formerly director of the National Research Council of Canada and now a consultant on adhesives and adhesion, before the Plastics-Plywood Conference on July 13, at Seattle, Wash. The technique involves combining acetylene black with synthetic resin adhesives so that when electric current is applied by means of electrodes to the glue line the acetylene black acts as an electrical resistor, producing the heat necessary to cure the resin.

Experiments showed that the most satisfactory forms in which to apply the adhesive were to pre-deposit the black on a coarse-mesh cloth and coat this with the resin, or to coat the wood surfaces with the adhesive and lay the cloth with pre-deposited black on it between the surfaces. Paper also can be used as a carrier but the resulting glue line has unsatisfactory shear strength.

Any hot- or cold-setting synthetic-resin glue that has a reasonably long flow on fusion can be used. The range of allowable moisture content in the wood is broad. Dimensions of the assembly to be glued are immaterial so long as the voltage is adjusted for varying widths. Tapered joints are not allowable because there is no way to change the potential continuously. Stepwise alterations in width are permissible, however, since correspondingly adhered potentials can be applied to such sections. The technique is limited to flat and simple-curved sections.

One of the chief advantages of the technique is the saving in curing time, which can be varied from a few seconds to several minutes or more. Generally speaking, periods of from 5 to 15 min. in the press are considered suitable for an average amount of black and an intermediate potential. Normal wood-joining pressures are used and power requirements are small. No unusual press technique or construction is involved.

INDUSTRY AND SOCIETIES

NEWS • READER LETTERS • MEETINGS

Patentable Ideas From Employees Encouraged by Ryan Aeronautical Company

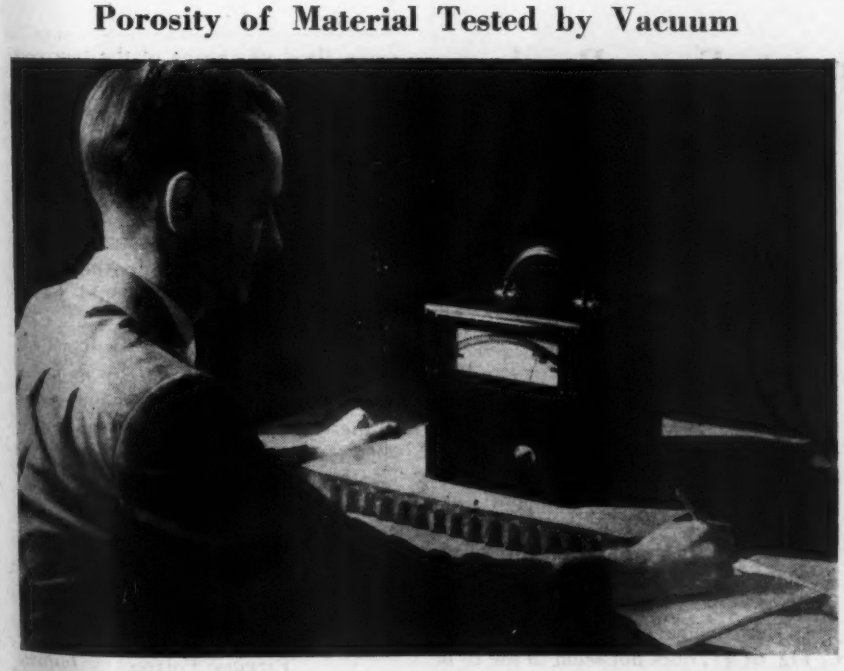
To ASSIST EMPLOYEES in developing ideas that may be patentable the Ryan Aeronautical Company has established the Ryan Employees Patent Remuneration Plan. Complete machinery is offered for making an idea grow into a worthwhile project and the employee-inventor participates in the company's income from royalties or from the sale of the patent.

Any employee who has an idea that he thinks is patentable enters into an "Invention Agreement" with the company and files a "Disclosure of Invention." The patent department of the company searches the patent if the idea is considered worthwhile. If an application for a patent and an assignment are signed, the employee receives $5 and is paid an additional $10 when a patent is issued.

If the company decides it is not interested in the invention, or believes it is unpatentable, the inventor is so notified within nine months of the date of disclosure. All interest in the idea is returned to the inventor, except that the company retains a free shop right to it.

The company determines whether to negotiate a license with a manufacturer or third party for producing or using the device, or to sell the patent. After a licensing arrangement is completed the employee-inventor is paid additional compensation consisting of a percentage, on a sliding scale, of any income derived by the company from the sale of such inventions or part thereof, or from any royalties which the company collects from licenses.

Porosity of Material Tested by Vacuum



Rate of flow of air or gases drawn through a material specimen by a vacuum determines the porosity of that material in an apparatus recently patented by Stuart H. Hahn and Robert H. Judson and assigned to B. G. Goodrich Company. The apparatus consists of a vacuum chamber placed in contact with the material to be tested, a constant-speed power-driven fan for evacuating the air, an outlet port for the air and a pressure gage to measure the vacuum.

Insulation Process Speeds Armature Treating

COST SAVINGS ranging from 50 to 90 percent and product improvement are advantages claimed for the Zanderoll process, developed by Sterling Varnish Company for the application of insulating varnish to armatures and stators. The process consists essentially of a combination of special methods of heating to unusual temperatures and applying insulation at speeds engineered to accommodate the varnish used. Any varnish that has been satisfactory for conventional dipping and baking can be used. The process is especially adaptable to the use of infra-red heating.

Research Group to Handle Southern Development

TO PROVIDE scientific research leading to the development of industry and agriculture in the South, the Alabama Research Institute has changed its name to Southern Research Institute and altered its scope accordingly. Headquarters remains in Birmingham. Individuals and business concerns are invited to contribute original funds for equipping the institute. In time, the organization is expected to become self-supporting.

The purpose of the institute is "to direct scientific research to the end that new and improved products shall be created; to provide research facilities to existing business establishments which do not have the equipment and

specialized personnel to undertake the solution of their own technological problems; and to afford facilities to those industries which, although having well-equipped laboratories of their own, find it advantageous from time to time to have certain types of work done in an atmosphere removed from all direct contact with their own production problems."

Color Films Explain Hydraulics

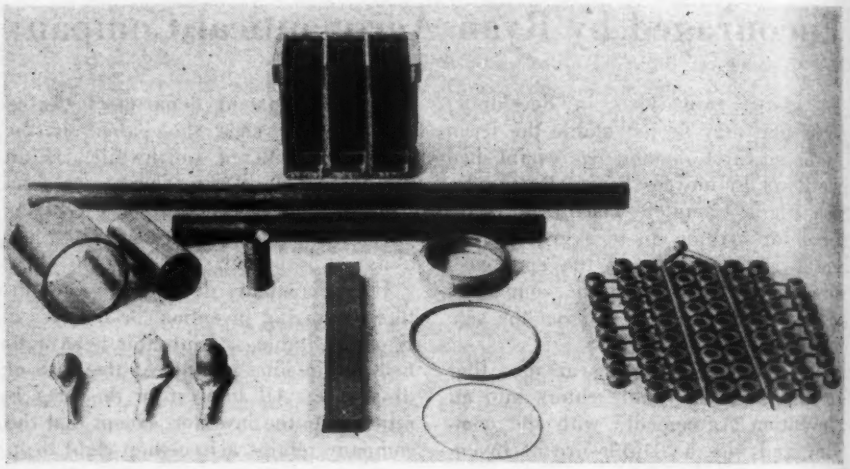
TWO MOTION PICTURE films describing the fundamentals of hydraulics, produced under the supervision of Adel Precision Products Corporation, are available for showing before service units, engineering groups and students. The films are 16-mm. animated color cartoons with sound and can be shown in 20 min. The first covers basic hydraulics and the second the fundamentals of fluid flow in hydraulics. Some of the points covered are practical applications of Pascal's law, the basic parts of hydraulic systems and their functions, hydraulic systems as efficient means of transmitting power with great force, flexibility of arrangement and positioning of hydraulic units, and the nature of liquids and fundamentals of flow.

New Machine Increases Molding Range of Plastics

BOTH THERMOPLASTIC and thermosetting materials, including natural and synthetic rubbers, can be injection molded or extruded continuously in a new molding machine developed by Chrysler Corporation. Faster production rates and larger mold charges are principal features.

The machine has produced a battery case, illustrated below, in less than 5 min. using 128 oz. of thermosetting plastic. It has also produced 144 rubber insulators, 68 of which are also shown below, in less than 3 min. using a single mold. Other parts which appear in the illustration are extruded thermosetting tubing, ends and noses of incendiary bomb cases, carburetor traps, thermoplastic bar, and synthetic rubber seal and gaskets.

Materials are fed from a hopper to a heated cylinder where a special churning apparatus keeps them evenly mixed. A wormscrew injects the charge under screw pressures up to 22,000 lb. per sq. in. through a nozzle clamped to a gate. When the mold is filled, back pressure automatically shuts off the feeder.



Discussions and Comments From Readers

RASCHE AND KLIGMAN DISCUSS UNIVERSAL SHAFTS

To the Editor:

As a teacher of mechanism I am very much interested in your excellent article "Universal Control Shafts and Their Development," published in the March, 1944, number of PRODUCT ENGINEERING, page 194. I should like to ask a few questions concerning some points that are not quite clear to me.

1. As I understand Fig. 5, the mechanism shown is for connecting two shafts or spindles, one passing through A, the other through B, the shaft at A being connected to shaft AD by a pair of bevel gears, and the shaft at B being connected in the same manner to shaft BG. Am I right about this, or is the mechanism simply for connecting the two coplanar shafts AD and BG by universal joints in such a way as to avoid an obstacle?

2. For the case shown in Fig. 5, $r_1 = r_2 = r_3 = r_4$ is assumed. Is that necessary? It doesn't seem so to me.

3. For each of the several cases treated there is the assumption that the driving shaft, the intermediate shaft or shafts and the driven shaft must be coplanar. It is my understanding that no such assumption is necessary.

4. The maximum value of the "angle of bend" is assumed to be 30 deg. Where the mechanism is manually operated and ball bearings are used in the four joints of the universal joints it is my impression that this angle can be considerably larger than 30 deg. Am I right or not? It is a fact, is it not, that the main reason for keeping the angle small is to reduce inertia; hence, there doesn't seem to be any reason why this angle should be as small as 30 deg. except where the speed exceeds 60 or 75 r.p.m.

5. The construction for finding point C, Fig. 6(A), does not seem to me to be correct. Isn't the correct construction as follows: About A and B, respectively, with radii $r_1 \sin \propto$ and $r_2 \sin \propto$, describes circles. Line CD is then one of the four common tangents to these two circles. The conditions of the problem make clear which one of the four common tangents should be taken.

6. Should not a fourth condition be added to the three given at the beginning of the article as necessary for an angular velocity ratio of unity in the case of Hooke's universal joint? Should it not, in other words, be stated that the two forks fastened to opposite ends of an intermediate shaft should be coplanar?

7. For the case of Fig. 7 why not connect shafts AK and BL by a pair of bevel gears at the point of intersection of these two shafts and thus reduce considerably the space occupied by the mechanism? I can see no reason why this simplification should not be adopted. Of course, the bevel gears for my solution would be somewhat more expensive than those given, but surely this would not be a very serious objection.

—WILLIAM H. RASCHE
Virginia Polytechnic Institute

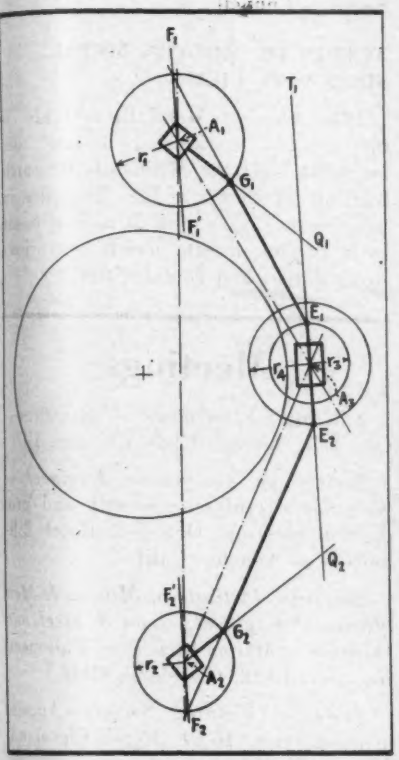
To the Editor:

I shall attempt to answer Professor Rasche's questions paragraph by paragraph.

(1) Either assumption may be cor-

rect. In most of the cases which we handle, *A* and *B* are bevel-gear boxes. However, in some cases, two coplanar control shafts *AD* and *BG* (not parts of bevel-gear boxes) are to be connected by universal shafts in such a way as to avoid an obstacle.

(2) You are quite right. It is not necessary to have $r_1 = r_2 = r_3 = r_4$. The accompanying sketch shows the con-



Construction: Draw FF' through A parallel to Q_1 Q_2 and thus locate points F. Draw FE and thus locate points G. Join G to E and A.

struction for the general case where the above radii are not equal.

(3) With the conventional type of universal shaft, that is, one that is outfitted with Hooke's joints at the ends, the driving and driven shafts (called "control shafts" in the article) must be coplanar if their angular velocities are to be the same at all times.

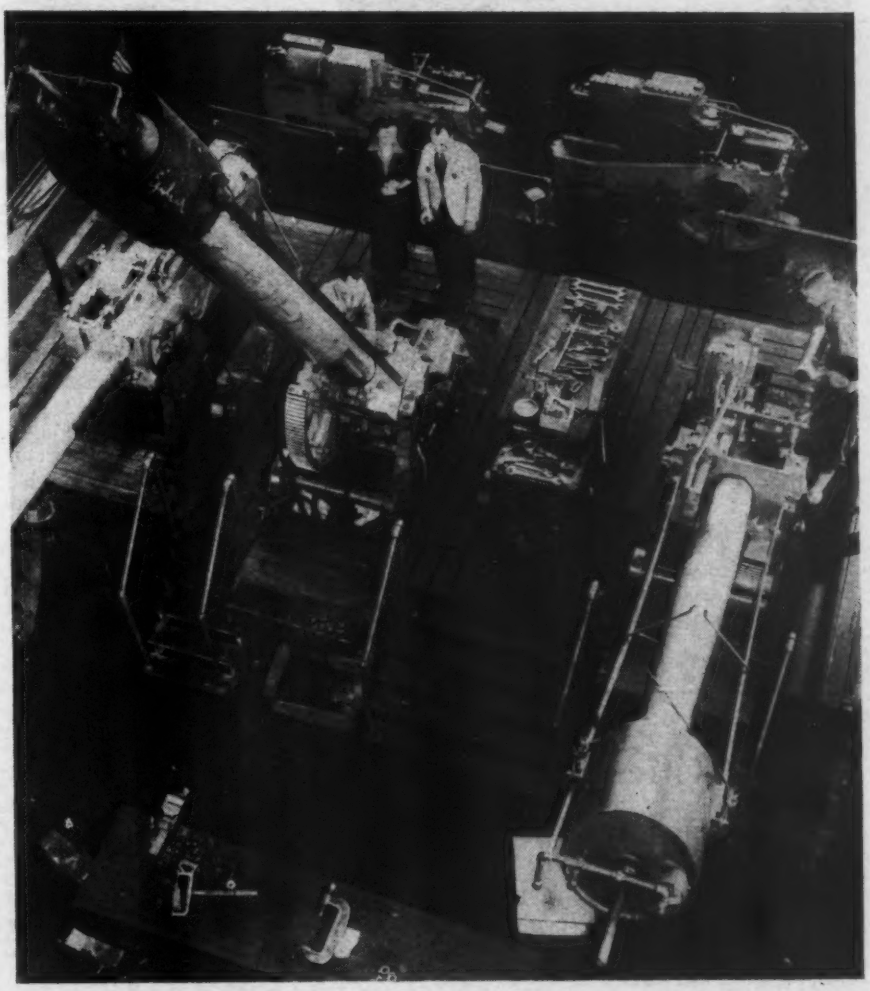
(4) In actual practice the "angle of bend" in the universal shafts is held to a figure which is much lower than 30 deg., usually 15 deg. or even less. Universal shafts with "bend" capacity up to 15 deg. are standard with manufacturers and are carried in stock. In cases where the shafts revolve slowly and no inertia forces of consequence are involved, angles greater than 15 deg. and smaller than 30 deg. require universal shafts, which are carried by the manufacturers as "specials." It is feasible, of course, to build Hooke's joints with greater capacity than 30 deg. The writer has not had any experience with such.

(5) I do not see wherein the construction offered differs from the one shown in the article. Inspection of Fig. 6(*A*) shows that line *CD* is drawn so that it is a common tangent to the circles described around *A* and *B* with the radii $r_1 \sin\alpha$ and $r_2 \sin\alpha$, respectively. The method suggested is thus the same as that given in the illustration, except that graphic construction is "short cut" by introducing a bit of computation (pertaining to $r_1 \sin\alpha$ and $r_2 \sin\alpha$). Both methods are, of course, cut-and-try as concerns arriving at the smallest value of α consistent with practicable clearance between *CD* and the interfering body.

(6) The two forks at the end of the intermediate shaft must be properly aligned so that this member presents an elementary link with axes of two holes (or pins) parallel. This point should have been brought up specifically, even though it is a recognized and standard feature of all universal shafts commonly available.

(7) I must disagree as to what is most practical—standard right-angle bevel-gear box with long universal shafts, or special (non-right angle) bevel-gear box with shorter universal shafts. My own experience in actual installations has been that usually no extra space need be occupied by the machinery, of which the control leads are just a part. On the other hand, the benefit of using only one type of bevel-gear box, viz., right-angle type, results in standardiza-

5-In. Guns Tested Without Firing



Barrel-like devices fitted over the muzzle of 5-in. naval guns allow inspectors at the Westinghouse Naval ordnance plant to observe recoil action, watching the performance of various parts in relation to each other. A piston in the cylinder pushes the gun barrel back into full recoil position, then allows it to return to normal, the cycle being just fast enough to watch the loading and firing mechanism. On a range this action would be too fast to see.

tion of this element in control leads and, thus, greater economy. Referring again to past experience, there was only one instance in the writer's practice when a smaller-than-90 deg. angle box was used because of space limitation; in that case, subsequent records revealed it would have been more economical, even though less efficient, to use two standard right-angle boxes rather than one special bevel-gear box, built for the occasion.—A. R. KLIGMAN

"Dust Bowl" Tests Military Vehicles

Life of mechanical parts of military vehicles that are used in desert warfare and that are operated over dirt roads is tested in a "dust-bowl" laboratory by Studebaker Corporation. Wind velocity and dust intensity are controlled by a series of air jets and miniature windmills. Dust can be concentrated as high as 0.07 grams per cu. ft. of air. Steering, clutch, brake and accelerator controls are operated from a sealed booth. With the vehicle mounted off the floor, simulated driving over rough terrain is achieved by eccentric weighting of the wheels. Paddles on the wheels increase agitation of the dust particles.

Activities Among Technical Societies

METAL FINISHING RESEARCH FELLOWSHIP ESTABLISHED

To conduct research on metal finishing, a fellowship has been established in the Chemical Engineering Department of the College of Applied Science, Syracuse University, by the Du-Lite Chemical Corporation. The establishment of this fellowship is part of the company's postwar expansion policy in "Chemifinishing" of metals, which includes the development of new finishes and the study of application requirements.

ELECTRONICS CONFERENCE TO EMPHASIZE APPLICATIONS

Engineering developments and applications will be emphasized at the National Electronics Conference to be held October 5, 6 and 7 at the Medinah Club in Chicago. The purpose of the conference is to serve as a "national forum on electronic developments and their applications." The program provides technical meetings for the presentation of original papers, forums for the review and correlation of recent electronic developments in various fields, and interchange of ideas, methods of approach and techniques between those working in the many fields of electronics. Sponsors of the conference are Illinois Institute of Technology, Northwestern University, Chicago Section of the Institute of Radio Engineers and Chicago Section of the American Institute of Electrical Engineers, with the cooperation of the Chicago Technical Societies Council.

ACTION OF MOLTEN METAL SHOWN IN FILM

"The Flow of Metal Into Molds" is the title of a two-reel, 16-mm. film available from the Meehanite Research Institute of America, Inc. The film, in color, shows the action of molten metal as it is poured into molds of various sizes, shapes and complexities.

Meetings

National Electronics Conference—Oct. 5-7, Medinah Club, Chicago, Ill.

Society of Automotive Engineers—National aircraft engineering and production meeting, Oct. 5-7, Hotel Biltmore, Los Angeles, Calif.

American Institute of Mining & Metallurgical Engineers, Iron & Steel and Institute of Metals Divisions—Fall meeting, Oct. 16-18, Cleveland, Ohio.

American Welding Society—Annual meeting, Oct. 16-19, Hotel Cleveland, Cleveland, Ohio.

American Society of Metals—National metal congress and annual meeting, Oct. 16-20, Public Auditorium, Cleveland, Ohio.

Society for Experimental Stress Analysis—Annual meeting, Oct. 17-20, Hotel Carter, Cleveland, Ohio.

American Industrial Radium & X-Ray Society—Annual meeting, Oct. 18-20, Hotel Hollenden, Cleveland, Ohio.

Electronics Parts & Equipment Conference—Oct. 19-21, Hotel Stevens, Chicago, Ill.

Society of Automotive Engineers—National fuels and lubricants meeting, Nov. 9-10, Hotel Mayo, Tulsa, Okla.

Society of the Plastics Industry—Fall convention, Nov. 13-14, Hotel Waldorf-Astoria, New York, N. Y.

American Society of Mechanical Engineers—Annual meeting, Nov. 27-Dec. 1, New York, N. Y.

National Exposition of Power & Mechanical Engineering—Nov. 27-Dec. 2, Madison Square Garden, New York, N. Y.

The Economic Reconstruction of Europe

THE time is fast approaching when allied and enemy populations alike will demand a blueprint for the economic reconstruction of Europe. The peace plans following this World War will be written piecemeal, and by experts, at a series of continuing conferences, such as Hot Springs, Bretton Woods, Dumbarton Oaks and Quebec, each tracing a new pattern for negotiation and each dealing with a single, specific problem. In the drawing of these plans, the United States, as owner of more than half of the world's industrial capacity, controller of the only great credit reservoir, and possessor of the largest force of highly skilled technicians and management engineers, has heavy responsibilities which its industrial, financial, agricultural and labor leaders cannot evade.

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Just what is the problem which the world's business leaders must help solve in Europe?

The best safeguard of peace is economic opportunity—a good chance for all peoples to raise their standard of living by their own ingenuity, foresight and industry.

Frustrated and disappointed peoples, who view the future with misgiving rather than hope, breed fanatical demagogues who seek to divert nations from their ills and disappointments by promising military glory and conquests.

Consequently, an important step in building a secure and lasting peace is to open the doors of opportunity to the peoples of Europe.

The greatest obstacle to opportunity in Europe has been economic nationalism.

The economic tradition of the Continent always has been highly nationalistic. The national feeling generated by the first World War, and the political autonomy conferred upon many peoples by the peace treaties, led to a great growth of economic restrictions. This trend was accentuated by the depression and by the military plans of the Fascists and Nazis. Hitler had to show his people they could be fed even if a blockade was imposed again. The inevitable result of these influences was to carry self-sufficiency to tragic extremes.

Economic nationalism holds down the standard of living of Europe in two ways:

1. It prevents the rise in most European countries of low-cost mass production.
2. It operates against an efficient geographical division of labor, preventing nations from doing what each can do best.

Great machines require great markets. One great machine of which the United States has many and Europe few is the continuous strip steel mill. At the outbreak of the war we had twenty-eight such mills of various sizes, England but one, and Continental Europe one. A building containing one of these machines is more than a quarter of a mile long and the minimum cost of the mill is almost $25,000,000. Only the prospect of a mass market justifies production on this vast, but highly economic basis.

The wasteful geographical distribution of production is shown by the agricultural policies of Italy, France and Germany.

In the 1930's, when lard sold for less than 8¢ a lb. in the United States, it cost 32¢ a lb. in Germany. In Italy and Germany imports of wheat were banned and its production at home was heavily subsidized. By the middle of the 1930's, wheat sold for $1.55 a bushel in France, $1.97 in Czechoslovakia, $2.29 in Germany, and $2.47 in Italy. At the same time the United States and the other efficient world producers and exporters (Canada, Australia and Argentina) were *restricting* production and were unable to average more than about 75¢ a bushel for their wheat.

Economic unity in Europe must ultimately mean a freedom to trade not greatly different from what we have within the United States. Given economic unity and the large markets which go with it, efficient mass production will develop. With Europe receiving cheap supplies of such staple foods as wheat, pork, lard and dried fruits from overseas, European farmers can prosper by specializing in producing fresh foods—butter, cheese, eggs, fruits, vegetables.

Then European agriculture will be more prosperous producing its specialties, and our agriculture (and that of the other great efficient surplus-producing countries as well) will have greatly expanded markets for our staples.

With a cheaper food supply for Europe—yet one yielding a better price for our agriculture—European labor will live better. Labor now used uneconomically for agricultural production will be released for industry. With big machines and semi-automatic processes European labor can produce more steel, automobiles, furnaces, plumbing and electrical appliances to advance its standard of living in coming decades, as the United States has done in past decades.

A rising standard of living in Europe will bring

Europeans to view peace with optimism and hope. And world trade grows as confidence and prosperity widen.

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How would a Europe which possesses economic unity appear to us on this side of the Atlantic?

It would be a prosperous Europe that would have strength in its advancing industries, but as the single great agricultural deficit area of the world, it would be dependent upon overseas supplies for vital agricultural staples. This dependence upon overseas agricultural supplies would be greatest for industrial Germany. Some people believe that a strong Europe would be a threat to world peace. More important, however, is the fact that a strong and prosperous Europe would not be a frustrated Europe. It would have found a way to achieve a rising standard of living. Furthermore, a prosperous Europe would, economically, be a dependent Europe because, although the European industrial worker would use more and cheaper food, he would have it only as long as he maintained the peace.

A prosperous Europe would be of special advantage to American agriculture (if we do not keep on pricing ourselves out of the market) and of great advantage to American industry.

The British policy of buying agricultural staples from abroad, for example, made her, a nation of only 45,000,000, the purchaser, in 1937, of $250,000,000 of all kinds of agricultural products from the United States. In the same year the rest of Europe (exclusive of Russia), with a population of 325,000,000 purchased only $300,000,000 of our agricultural products. But with more sensible organization of its agriculture, Europe could be expected to buy more than one billion dollars of agricultural products from us.

By far the greatest market for an expanded European industry will be Europe itself.

For American industry, there will be growing markets in Europe as industry expands. Experience shows that the trade between different highly industrialized areas is large. This country's biggest export markets have been with its keenest competitors—Britain, Canada, Japan, France and Germany.

Before the war, Europe, with two and one-half times the population of the United States, had only one-sixth as many automobiles.

If Europe (exclusive of Britain and Russia) were to motorize proportionately, it would need 75,000,000 automobiles. With normal depreciation this would ultimately mean 10,000,000 cars to be produced annually to replace worn out cars.

If one still wonders about the immense number of things Europe might produce *for herself*, let him calculate the highway expenditures, the filling and repair station businesses that must be equipped and maintained; and the doubling of the steel production that would be required to make the automobiles themselves and to reinforce with steel even a moderate amount of additional concrete highways.

Another example is the electrification of Europe. With two and one-half times our population Europe's consumption of electrical energy would be 175 million electrical H.P., if the European worker were to have the advantage of as many H.P. as the American. Yet, just prior to the war, Europe's installed operating capacity was only about 40 per cent of this figure.

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What has been sketched for Europe is actually much more nearly a page from the economic history of the United States than it is mere prophecy about a desirable future for a Europe at peace. But how can it be achieved? And what is our part to be in helping to bring it about?

Economic unity can be provided for the sovereign states of Western Europe by the peace treaty or treaties adopted at the end of the war. The provisions for securing *economic unity* in Europe should specifically cover:

1. Substantial freedom for persons and enterprises to do business anywhere in Europe.
2. Reasonably free movement throughout Europe of persons for employment, recreation and education.
3. Greatly increased freedom of trade:
   a. Within Europe—through the application of a Europe-wide agreement reducing the tariffs among all European countries to a maximum of 10 or 15 per cent.
   b. With the rest of the world—through reduction of European tariffs on goods bought from overseas. This would call for generally lower levels on manufactured goods, and for the removal (after a reasonable period of progressive reduction) of tariffs on all agricultural foodstuffs and most industrial raw materials.
4. A special currency provision requiring as nearly as practicable complete currency stabilization for all countries of Western Europe among each other.
5. Creation of an agency (with adequate revenues) through which all Europe-wide business and other affairs affected by these agreements would be administered for a minimum period of twenty-five years.

This would permit the economic unity of Europe to be substantially achieved. During this period, assistance in administering the provisions would be given by officials of the United Nations.

Near the end of such a period arrangements could be made for a vote in the European countries on whether or not to continue the "unification provisions." If the vote were in the negative, the United Nations would have proper warning that additional safeguards would be necessary to prevent war.

The suggestions made in this statement aim at securing economic unification of Europe and thereby promoting the possibilities of permanent peace in Europe.

The realization of these possibilities throughout the postwar years requires a freely expressed public opinion in Europe to guide all who share the responsibility for bringing peace to Europe and to the world.

James H. McGraw, Jr.

President McGraw-Hill Publishing Company, Inc.

New Books

Modern Wood Adhesives

THOMAS D. PERRY, 208 *pages, 6x9 in., red clothboard covers. Published by Pitman Publishing Corp., 2 W. 45th St., New York* 17, *N. Y. Price* $3.

All types of adhesives used for wood and plywood are brought up-to-date in a single volume with the publication of this book. The author, a widely known authority on the preparation and use of wood and adhesives, has not only covered the important commercial adhesives but has at the same time collated the latest information on the synthetic-resin glues that have recently come into prominence. Beside the sections dealing with the different classes of adhesives the chapters covering comparative qualities, fundamentals of heat and pressure as applied to gluing technique, impregnated products and testing methods should be helpful to designers and engineers.

Guide to Weldability Of Steels

Welding Research Council. 90 *pages, 9x6 in., paper covers. Published by American Welding Society, 33 W. 39th St., New York* 18, *N. Y. Price* $1.

Describes a system for predetermining and preserving a desired ductility in the heated zone of higher carbon and low-alloy steels during welding. The book is also planned as an instruction manual, with step-by-step examples showing the use of the system to select steels and to predict welding conditions necessary for the preservation of desired ductility in the heated zone. Aside from the data in the book only two tests are required—an end quench on the steel and a notch-bend test of the steel.

Practical Design for Arc Welding

ROBERT KINKEAD. 100 *pages,* 8½x11 *in., gray clothboard covers. Published by Hobart Bros. Co., Box EW* 98, *Troy, Ohio. Price* $3.50.

One hundred design plates that illustrate the possibilities of arc welding in the fabrication of a wide variety of machine frames and other parts from plate, sheet, standard steel shapes and tubing have been assembled into book form. Previously most of the plates had been published in loose-leaf form and distributed in small lots. This is the first of three volumes to be published. The reason for this published work is the fact that it is often helpful in starting a design to see what other designers have accomplished with welded design. To make the book more practical from a reference and design standpoint, a complete work sheet in graph and record form is on the facing page of each design plate. These can be used for notes, estimates and sketches. A cross-reference index gives plate numbers that involve more than 90 of such specific details as bases, bosses, columns, frames, gussets, lugs and stiffeners. Standard welding symbols are used on the plates and explained in the opening pages.

Plastic Horizons

B. H. WEIL *and* V. J. ANHORN. 169 *pages,* 5¼ x 7½ *in., brown clothboard covers. Published by Jaques Cattell Press, Lancaster, Pa. Price* $2.50.

Anyone, technical or non-technical, who has not made a study of plastics will find some useful information in this book. It is written for the general public but, probably because the authors are engineers themselves, it will also appeal to technical men. The information is basic and fundamental and emphasis is on applications—past, present and future.

Bulletins

Resin Bonded Plywoods

Published by Plastics Industries Technical Institute, 186 S. Alvarado St., Los Angeles, Calif. Three sections, 30, 22 *and* 25 *pages, respectively,* 8½x11 *in., buff cardboard covers.*

These three sections are supplemental lessons to the P.I.T.I. home study course in plastics. Section 35a deals with adhesives; 35b covers aircraft woods; and 35c describes molding and forming techniques. Halftones and line cuts are profuse and aid in clarifying the text.

Solution of Vibration Problems By Use of Electrical Models

C. R. FREBERG. 42 *pages, 9x6 in., paper covers. Bulletin Research Series No.* 92. *Published by Purdue University, Lafayette, Ind. Price* 25 *cents.*

Summation of the results of an investigation which was undertaken in an attempt to eliminate some of the difficulties encountered in analytical and trial-and-error methods of solving vibration problems. Important subjects covered are equations and models for mechanical vibrating systems, equations and models for an electrical circuit, analogy between mechanical and electrical systems, and method of laying out equivalent electrical circuits.

Flow of Water Through Small Swing-Check Valves

F. W. GREVE. 15 *pages, 9x6 in., paper covers. Engineering Experiment Station Research Series No.* 88. *Published by Purdue University, Lafayette, Ind. Price,* 15 *cents.*

Description, with results and conclusions, of an investigation to determine the loss of head in the flow of water through ½, ¾, 1, 1½ and 2 in., brass swing-check valves. Tables of test conditions and observations for each size valve are given, also graphs showing the relation of head loss to velocity of flow and relation of head loss to the Reynolds number. A graph is also included for the 2-in. valve showing the relation of the ratio of lost head to velocity head, to velocity of flow and to the Reynolds number.

Natural and Synthetic Fibers

M. HARRIS *and* H. MARK, *editors. Loose-leaf monthly digest,* 6½x9½ *in. First issue,* 64 *pages. Published by Interscience Publishers, Inc.,* 215 *Fourth Ave., New York* 3, *N. Y. Price* $60 *per year.*

This abstract service is devoted to the field of the chemical and physical structure of fibers, the intrinsic properties of fibers and fabrics and the processing of fabrics based on these properties. The first issue contains the table of contents for the service and several abstracts from American, British and German periodicals and patents.

Planning the Future Of Your Business

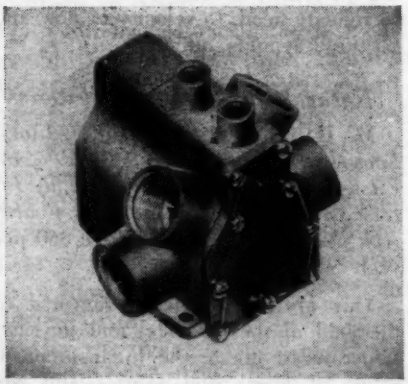
Prepared by the Association of Consulting Management Engineers for the Committee for Economic Development, Field Development Div., 285 *Madison Ave., New York* 17, *N. Y.* 24 *pages,* 8½x11 *in., paper covers. Available through local Committee for Economic Development.*

This handbook for industrial employers replaces the former handbook, "Plan Postwar Jobs Now." It sets forth the steps to be taken and the questions that management consultants would review if they were employed to study the post-war requirements of a business organization.

NEW MATERIALS AND PARTS

Four-Way Control Valve

Cable controls, push-pull rods and mechanical controls are eliminated with No. 13261 remote-positioning four-way control valve. It permits regulation of high-pressure hydraulic systems with the Isodraulic remote-control system. Unit illustrated has a 16-gal. per min. flow at 3,000 lb. per sq. in. and is designed for ¾-in. lines. Units for other flows and pressures are available. The valve is adaptable for a variety of control installations in combination with other standard units, such as positioning of wing flaps, dive brakes and



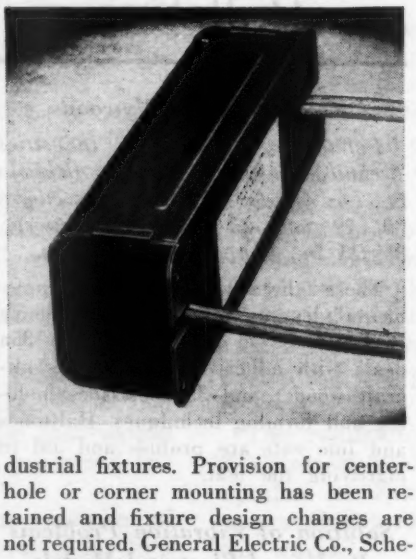
steerable nose wheels in aircraft as well as hydraulic operation of roadworking, automotive and marine equipment. Adel Precision Products Corp., Burbank, Calif.

Synthetic-Rubber Adhesives

Development of a new line of synthetic rubber adhesives has been announced. One is for general utility use and will adhere to almost any clean surface. Synthetic cements are available for heat vulcanization, air curing or cold adhesions. The compounds are suitable for gluing fabric, leather and synthetics to themselves or to each other. These adhesives have a non-toxic solvent. For metal adhesion, two special cements in the Plastilock 300 Series, have been developed. The first is used with vulcanized Neoprene when it is bonded to porcelain, metal or other materials, while the second is used with uncured Neoprene for the same purpose. Military products on which these cements have already been successfully used include life-saving boats, rubber mattresses, belts, target tubes, tank crash pads, pontoons, tank linings, land mines, brake tubes, balloons, diving suits and in submarines. B. F. Goodrich Co., Akron, Ohio.

Two-Way-Lead Ballasts

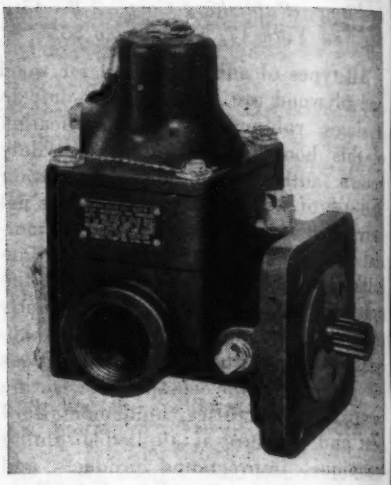
For operation of Mazda F lamps, two-way-lead ballasts are currently available in the following ratings: Tulamp 30- and 40-watt, standard cross-section; Tulamp 40-watt, high voltage; Tulamp 100-watt; three-lamp 40-watt; and Forlamp 100-watt. With leads that can be brought out at either the ends or the bottom of the ballast cases, the ballasts are interchangeable with both the superseded leads-out-the-end and leads-out-the-bottom ballasts of the same ratings. They are applicable to exposed or enclosed mounting on both commercial and in-



dustrial fixtures. Provision for center-hole or corner mounting has been retained and fixture design changes are not required. General Electric Co., Schenectady 5, N. Y.

Engine-Driven Fuel Pump

Originally designed for aircraft, but adaptable to other applications for liquid handling, an engine-driven fuel pump weighs 2¾ lb. and delivers 400



gal. per hr. at 2,500 r.p.m. It also has a pressure range from 6 to 35 lb. per sq. in. The pump is precision-built with balanced-type relief valves and with low-temperature shaft seals. It is designed to withstand extreme temperature ranges. It was formerly known as U. S. Army type G-9, which was designed to meet Specifications AN-P-52 and AN-P-56. Romec Pump Co., 100 Abbey Rd., Elyria, Ohio.

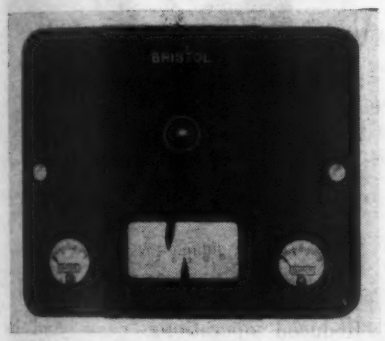
Ceramic Wire Insulation

Ceroc 200 is a thin ceramic coating deposited on copper, nickel and other types of wire. When applied to copper wire it maintains desirable electrical characteristics at a continuous operating temperature of 200 deg. C. Because of its inorganic composition, Ceroc 200 is believed to meet all requisites of a Class C insulating material as classified under A.I.E.E. standards. Space factor is good because the coating is thinly deposited on the wire. Thermal conductivity is high. Moreover, the coating is uniform and makes for smooth, level winding in a minimum of space. Present preferred wire sizes for applying Ceroc 200 are from 3 to 30 mils in copper wire (No. 40 to No. 21 AWG) and from 1½ to 12 mils (No. 46 to No. 28) in nickel wire. Ceroc 200 is sufficiently flexible that round coils can generally be wound satisfactorily on existing equipment. In the case of rectangular coils or motor

armatures, however, winding technique may require modification to assure that the wire is not stretched more than 10 percent. Sprague Electric Co., North Adams, Mass.

Air-Operated Controllers

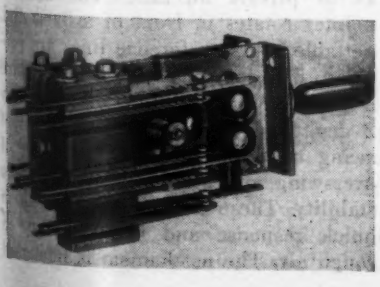
Development of a new series of indicating air-operated control instruments, known as the Model 93 Series, built for controlling temperature, pressure, vacuum, liquid level and humidity, has been announced. The controllers operate on the Free-Vane principle. They have a throttling range of from ½ to 15 percent with the adjusting mechanism arranged so that changes in the throttling range can be made without tools. The controllers can be set to control at any value within the range of the instrument by turning the control pointer to the desired value. They are built so that they can be changed by a finger adjustment from reverse to direct action or vice versa. Typical applications include



control of temperatures in ovens, cookers, retorts, plating tanks and soft metal pots and the control of steam pressure, pressure in retorts and back pressure or digesters. Bristol Co., Waterbury 91, Conn.

Master Cam-Lever Switch

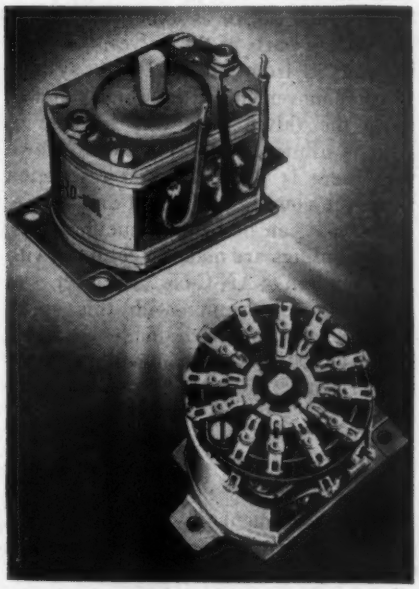
Designed for use on electronic and communications equipment and wherever multiple circuits must be controlled, master cam-lever switch Model MCL-CS has a positive positioning cam that has roller detents which eliminate friction and contact bounce. Coil springs are used on both sides of the cam so



that equalized pressure is assured regardless of the number or arrangement of contact assemblies. The switch is static shielded and is of non-corrosive construction. All contacts can be removed from the frame by removing a single bolt. Control knob can be supplied with light or stiff action. Contact rating is 10 amp., 125 volts a.c. and 2 amp., 125 volts d.c. General Control Co., 1200 Soldiers Field Rd., Boston 34, Mass.

Rotary Relay

Operating on a rotating balanced principle, Ro-trol is designed especially for applications involving severe vibration, temperature and humidity. The basic unit is a compact driving mechanism providing up to 30 deg. of clockwise or counterclockwise rotation. When used to operate switch wafers, it makes a relay providing many contact arrangements adaptable for spaced-wafer switches or switches in separate compartments. Where switch wafers are not used a special self-contained coil break switch is provided. The unit measures 2½x1½x1¾ in. Price Bros. Co., Frederick, Md.



Voltage Regulator

Designed for use with a.c. generators using direct-connected, belted or motor-driven exciters, 50-60 cycles standard, the Synchrostat voltage regulator consists of a metal-enclosed unit adaptable for generator switchboard mounting, and for mounting on top of the generator in "packaged" power units. Voltage regulation is ±2 percent. The regulator quickly responds to load changes to restore generator voltage to normal.

It is of the synchronous-contact type. Vibrating tungsten contacts of the regulator relay operate every half cycle of the wave to insert and remove a resistance in the shunt field circuit of the generator exciter. Regulating action is obtained by the relative time interval that the relay contacts are open or closed, the time interval being determined by the voltage from the generator on the regular relay coil. All operating parts are mounted on the back of a hinged door for ease of inspection, with regulator controls on the door front. A damping transformer supplies a "biasing" effect across the relay coil. Electric Machinery Mfg. Co., Minneapolis 13, Minn.

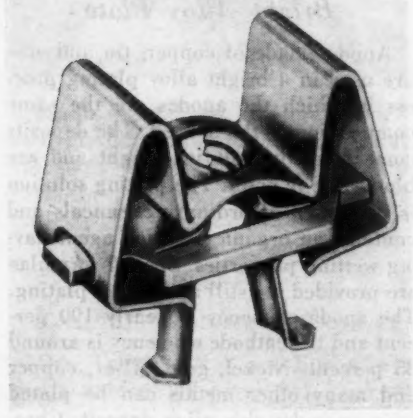
Bright Alloy Plate

Anodes made of copper, tin and zinc are used in a bright alloy plating process in which the anodes are the same composition as the deposit. The deposits come from the solution bright and are blue-white in color. The plating solution is composed of ordinary chemicals and contains an organic addition agent having wetting properties. Special formulas are provided for still and barrel plating. The anode efficiency is nearly 100 percent and the cathode efficiency is around 35 percent. Nickel, gold, silver, copper and many other metals can be plated over or under this alloy deposit. Chromium can be applied directly over the deposit, although the work should be given a light anodic cleaning to remove the film resulting from the wetting agent. Except in cases where the alloy deposit is to be further plated, special rinses or treatments are not required. The deposit can be soldered using rosin as a flux. Outstanding property of this coating is its corrosion resistance when applied over copper or brass. A thickness of 0.0002 in. will withstand a 200-hr. salt spray test. The alloy is relatively brittle in heavy coatings; however,

it is seldom used in thicknesses over 0.0005 in. It is harder than nickel and its wear resistance is superior to normal nickel deposits. Even though the alloy is hard, when it is applied in thicknesses of not over 0.0002 in. it can be formed or rolled without flaking. The coating is non-magnetic in an electrical field. It is not recommended for application directly on steel when corrosion resistance is the primary requirement. Instead, a copper undercoat should be applied to obtain the full benefit of the low corrosion rate between copper and the alloy deposit. Hanson-Van Winkle Munning Co., Matawan, N. J.

Floating Cage-Type Nut

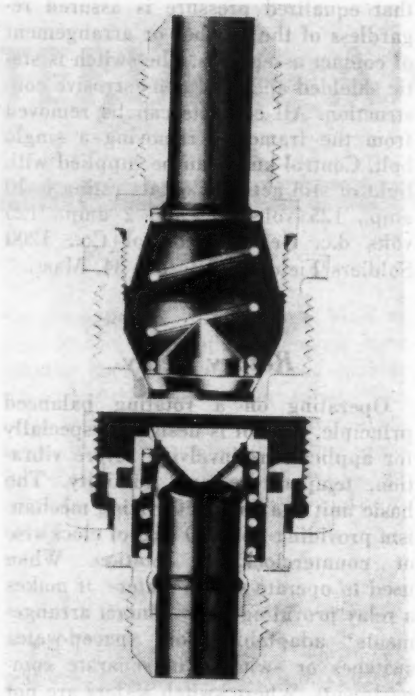
Originally designed for front mounting of aircraft instruments, a floating cage-type Speed Nut can be used for any type of blind attachment. It is available in two styles: A6939, made of brass and phosphor bronze, for use with standard 6-32 machine screws; and A-5939, made of spring steel, for use with standard 6Z sheet metal screws. Both styles are available to fit panel thicknesses from 0.062 in. up, and require an 0.171-in. dia. clearing hole to attach. The nut can be made in larger sizes. For installing, the cage is compressed and the legs inserted in the clearance holes. When pressure is released the legs bear against the sides of the hole with the turned out ends just clearing the back side of the



panels. The nut will hold tight against screw-tightening torque and the floating nut in the cage allows for misalignment. Tinnerman Products, Inc., 2041 Fulton Rd., Cleveland 13, Ohio.

Self-Sealing Coupling

Disconnection and reconnection of hydraulic or other lines without loss of fluid or inclusion of air is possible with a self-sealing coupling. Seal is effected by O-ring embedded in recess of body.



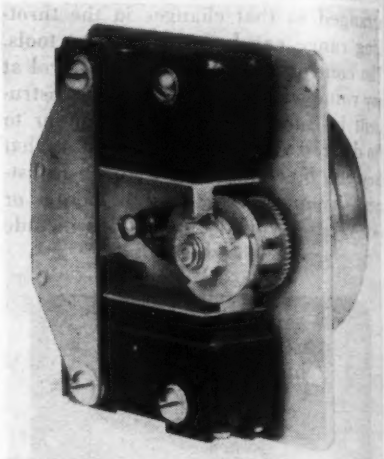
One half can be provided with a detachable mounting flange. When the coupling halves are connected the protruding portion of the left half makes contact with the sleeve of the other body. Simultaneously, all air is expelled between the mating parts of the halves, thus preventing it from entering the system. Further movement of the union nut will move the valves until free passage of fluid is allowed. Experience has shown that there is practically no restriction when the coupling is joined and, consequently, it can be used in suction lines. The couplings are made to conform with Specification AN-C-65. A set of couplings conforming with this specification has also been made available with AC-811 type end connections. Aeroquip Corp., 310 S. East Ave., Jackson, Mich.

Plastic Cement

Pliastic Cement is the name of a white fluid synthetic-resin adhesive that can be used in its natural state or reduced with water. Application is by brush, gumming machine, spreader, dipping, flow or spray gun. The film, when dry, is a semi-transparent, glossy, flexible coating with excellent heat-sealing properties. When used in the liquid state the adhesive can be applied to one or both surfaces, the speed of setting being dependent upon the porosity of the materials used. Suggested applications include combinations of paper; cardboard; wood; plywood; asbestos; cotton, wool and hair felt; abrasive grains; tinsel; glass beads; flock; plain or treated fabrics; cork; glass-fiber insulation; leather; plastics; porcelain; metals; stone; and many painted, lacquered and coated surfaces. Paisley Products, Inc., 1770 Canalport Ave., Chicago 16, Ill.

Two-Circuit Relays

Varied operation of one circuit in relation to a second is provided in Types TDSA and TDSB time-delay relays. They are arranged for surface mounting for either front or rear connection and are particularly designed to withstand momentary shocks. The time scale ranges from 2 to 120 sec. R. W. Cramer Co., Centerbrook, Conn.



High-Speed Copper Plating

Reduced operationg costs and increased production rates feature an improved high-speed copper-plating process. Potassium cyanide and other potassium salts are substituted for the sodium salts formerly used in the process, with further increases in current densities. Development of methods for producing the potassium salts in this country, and technical advances in their use in plating baths, made the substitution possible. E. I. du Pont de Nemours & Co., Wilmington 98, Del.

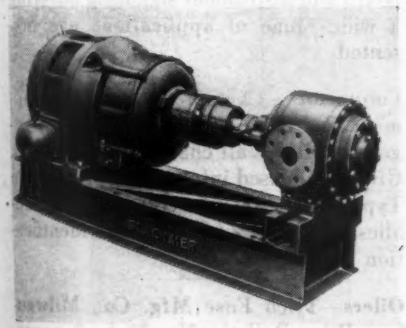
Directional Compass

Direct-reading magnetic direction indicator compass Type 2221 is adapted to passenger and cargo planes, as well as to private aircraft. The azimuth pointer rotates in front of a fixed dial. Settable course reference lines are provided. The instrument uses a standard 3¼-in. luminous dial, graduated every 2 deg., and combines a short time of swing or period with a low value of overswing and a high lateral dynamic stability. These characteristics result in quick response and high stability in rough air. The mechanism is immersed

in compass fluid. Wide range temperature and magnetic compensation are provided within the housing. Weight is 1.1 lb. Autoflight Corp., 2921 W. Olive Ave., Burbank, Calif.

High-Pressure Rotary Pump

Discharge pressures up to 500 lb. per sq. in. are produced in a rotary pump made of iron with bronze fittings. Rated capacities are 50 and 90 gal. per min. Standard motors with separate gear re-



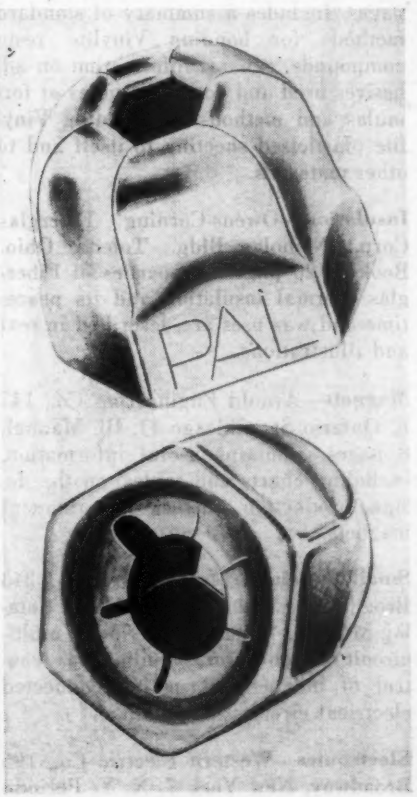
duction, or gearhead motors, can be used. Units are also available for engine drive. Large-capacity units are planned for the future. Several of the units have been furnished for pumping oils of various types, and they are designed for handling similar liquids having lubricating properties. The pumps employ the "bucket design" swinging vane principle. Blackmer Pump Co., Grand Rapids 9, Mich.

Side-Molded Iron Cores

Molded by applying pressure from the sides rather than the ends, a line of iron cores has outstanding advantages for permeability tuning applications at broadcast frequencies. Similar side-molded cores are now available for short-wave frequencies, including television and frequency modulation. In side-molded cores, any density resulting from molding pressure extends evenly over the length of the core, assuring uniform permeability with respect to length. Stackpole Carbon Co., St. Marys, Pa.

Self-Locking Nut

Featuring a triple grip, Type 6NAO locknut has a base like a standard Palnut, with six spring-steel jaws that fit the bolt thread. When the nut is tightened, the jaws close in around the bolt like the jaws of a chuck. Spring tension is also exerted upward on the bolt threads and downward on the nut base. The fastener has a third grip that is exerted on the bolt by the top portion of the nut. The sides of the nut have been extended up and in, but instead of having a closed top the ends are turned in, leaving a hole in the top slightly smaller in diameter than the outside diameter of the bolt. When the bolt extends through the top of the nut it forces the top open so that spring pressure is exerted on the bolt. This spring tension is constant and will hold the nut in any desired position on the bolt regardless of vibration. The nut can be used on metals or on bolts holding together parts made of glass, plastic and similar materials, where a resilient fastening is required that can be tightened without danger of fracturing relatively brittle materials. Palnut Co., 65 Cordier St., Irvington, N. J.

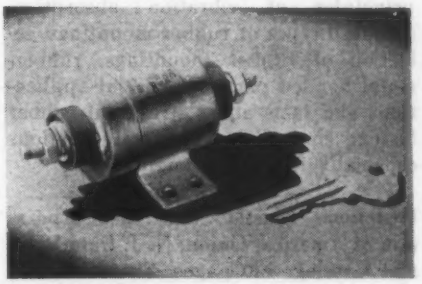


Sealing Compound

Made of Thiokol synthetic-rubber latex, a sealing compound known as Galco can be applied by spraying, brushing or slushing. The compound was developed especially for sealing airplane integral fuel tanks, but characteristics make it suitable for many other uses. It has a low diffusion rate, low solubility in aromatic fuel and water, and high adhesion to aluminum, steel, wood, and other surfaces. It will maintain a tight seal at extremes of temperature. Presstite Engineering Co., 3900 Chouteau Ave., St. Louis, Mo.

Noise-Suppression Capacitor

Reduction of radio-noise voltage from generators, inverters, motors and other equipment is the purpose of a Pyramol radio-noise suppression capacitor. The capacitors are of the thru-stud type with a terminal at each end. One line of a d.c. or a.c. power circuit can be "fed" through the unit, thereby reducing internal inductance and resistance and increasing filter efficiency for a given capacitance. The capacitors are especially effective in reducing radio noise at



higher frequencies. Dimensions are approximately 1¾ by 3⅝ in. and weight is 4½ oz. The units can be mounted in any position and will operate over a temperature range of 50 to —50 deg. C. The capacitors are rated 0-100 amp., 250 volts maximum a.c. or d.c., 0.55 microfarad. They are designed to meet vibration tests required by U. S. Army Air Forces Specifications. General Electric Co., Schenectady 5, N. Y.

Buna N Stock

Retaining tensile strength of over 1,000 lb. per sq. in. and elongation of over 100 percent after being subjected to aircraft engine oil at 300 deg. F. for 70 hr., Buna N stock 233-5 was designed for oil seals, oil rings and other applications requiring resistance to aromatic fuels. It also remains flexible at —40 deg. F. and has a low compression set. Los Angeles Standard Rubber, Inc., 1500 E. Gage Ave., Los Angeles, Calif.

Manufacturers' Publications

Glass Tubing—Fischer & Porter Co., Hatboro, Pa. Catalog Section 95-A, 8 pages. Indicates possibilities of Glo-Tech precision-bore glass tubing for various products.

Welding Symbols—Hobart Bros. Co., Hobart Square, Troy 1, Ohio. Chart. Gives basic characters of welding symbols recommended as standard by the American Welding Society.

High-Temperature Protection—Metallizing Engineering Co., 38-14 30th St., Long Island City 1, N. Y. Describes three processes that are used on iron and steel to prevent corrosion at high temperatures.

Vibration Resistance—Vibration Engineering Dept., Mechanical Goods Div., United States Rubber Co., 1230 Sixth Ave., New York 20, N. Y. Engineering Manual, 112 pages. Covers fundamental principles of vibration absorption, standard types of rubber mountings, selection of rubber mountings, rubber-metal bonded parts for special applications and facts about structural rubber in text, charts, graphs and illustrations especially for design engineers.

Fasteners—Elastic Stop Nut Corporation of America, Union, N. J. Data Book and Catalog, 120 pages. Size, material, class fit, axial load strength based on pull-test data, military requirements, weight, finish and other useful information on hex, anchor and clinch types of ESNA self-locking nuts is given for the benefit of design engineers.

Pump—Adel Precision Products Corp., Burbank, Calif. Brochure, 8 pages. Describes Series K metering pump, including performance curves and data on installation and uses.

Drive—Dept. 435, American Pulley Co., 4200 Wissahickon Ave., Philadelphia 29, Pa. Catalogs FBD-44, 24 pages; HT-44, 8 pages; and Bulletin Sj-44, 4 pages. FBD-44 describes and gives tabular data about flat-belt drive equipment; HT-44 covers Hi-Torque motor pulleys; and SJ-44 gives features, specifications and installation data on the Speed-Jack drive.

Stainless-Steel Sheets—American Rolling Mill Co., Middletown, Ohio. Handbook, 40 pages. Called "Design Data on High-Tensile Stainless-Steel Sheets for Structural Purposes," the handbook gives much information for accurately proportioning stronger, lighter aircraft and component parts.

Hydraulic Motor—Pump Div., Sundstrand Machine Tool Co., Rockford, Ill. Bulletin, 8 pages. Describes and illustrates features, operating principles, possible applications and engineering data of the company's fluid motors.

Rubber—B. F. Goodrich Co., 490 S. Main St., Akron, Ohio. Bulletin, 12 pages. Discusses the company's line of Vibro-Insulators; molded, extruded, lathe cut and sponge rubber products; rubber-lined tanks and valves; products made from Koroseal; V-belts; and cements.

Capacitors—Sprague Electric Co., North Adams, Mass. Catalog No. 10, 28 pages. Covers various types of dry electrolytic capacitors and features application information, including typical characteristic charts.

Plastic Bonding—Plastics Div., Carbide & Carbon Chemicals Corp., 30 E. 42nd St., New York 17, N. Y. Booklet, 16 pages. Includes a summary of standard methods for bonding Vinylite resin compounds, general information on adhesives used and detailed studies of formulas and methods for bonding Vinylite plasticized sheeting to itself and to other materials.

Insulation—Owens-Corning Fiberglas Corp., Nicholas Bldg., Toledo, Ohio. Booklet, 20 pages. Properties of Fiberglas thermal insulation and its peacetime and war uses are described in text and illustrations.

Magnets—Arnold Engineering Co., 147 E. Ontario St., Chicago 11, Ill. Manual, 8 pages. Contains useful information, including charts and tables, on the design, production and use of permanent magnets.

Small Switches—Metallic Arts Co., 243 Broadway, Cambridge 39, Mass. Catalog MM448, 4 pages. Selection of multi-circuit switches for simultaneous control of independent or interconnected electrical circuits is explained.

Electronics—Western Electric Co., 195 Broadway, New York 7, N. Y. Periodical, 36 pages. Revival of *Pick-Ups*, now known as *Western Electric Oscillator*, this publication is devoted to developments in communications and electronics.

Protective Coatings—Preferred Utilities Mfg. Corp., 1860 Broadway, New York 23, N. Y. Pamphlet, 12 pages. Describes White Hot and Pyro-Chrome protective coatings for use on glass, ceramics, refractories and metals where high heat resistance is needed.

Magnetic Drain Plugs—Lisle Corp., Clarinda, Iowa. Folder, 4 pages. Illustrates products on which the company's magnetic drain plugs are used.

Hydraulics—Aldrich Pump Co., Allentown, Pa. Bulletin 50, 60 pages. Contains useful hydraulic information and data for engineers.

Fasteners—Industrial Products Div., B. F. Goodrich Co., Akron, Ohio. Catalog Section 12050, 4 pages. Shows step-by-step installations, lists details of types available and indicates applications of Rivnut blind fastener which can be used as a nut plate, rivet or both.

Pilot Lights—Gothard Mfg. Co., 1300 N. Ninth St., Springfield, Ill. Catalog, 24 pages. Pilot light models for panel board and instrument signaling covering a wide range of applications are presented.

Connectors—Cannon Electric Development Co., 3209 Humboldt St., Los Angeles, Calif. Wall chart No. 3, 38x50 in. Gives condensed information on Cannon Type K and RK connectors and assemblies, including a selection and identfication guide.

Oilers—Trico Fuse Mfg. Co., Milwaukee, Wis. Bulletin No. 28-A, 2 pages. Thermal and bottle oilers are described and illustrated.

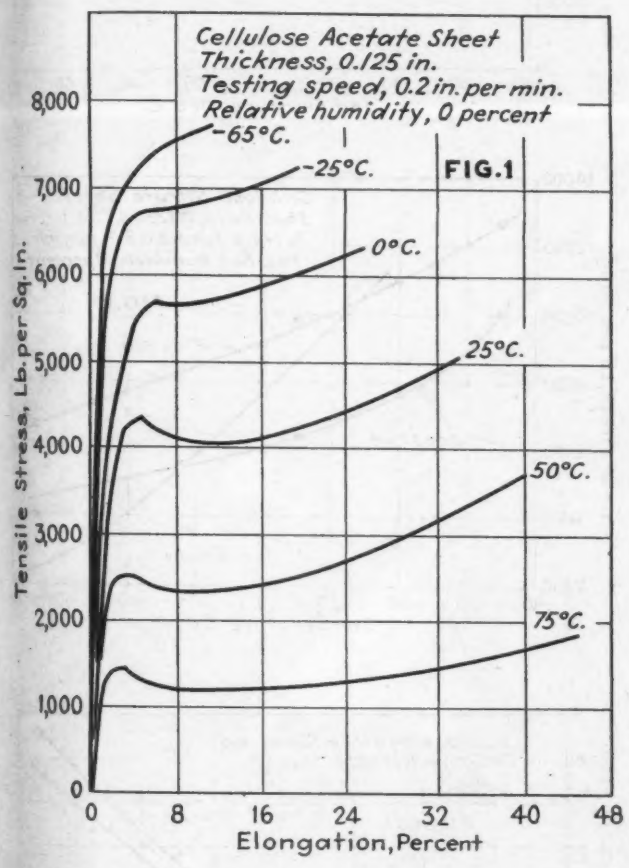
Microfilm—Microcopy Corp., 2800 W. Olive Ave., Burbank, Calif. Bulletin, 4 pages. Describes application of microfilming to penciled engineering drawings made on transparent paper and to other records, documents, drawings and maps.

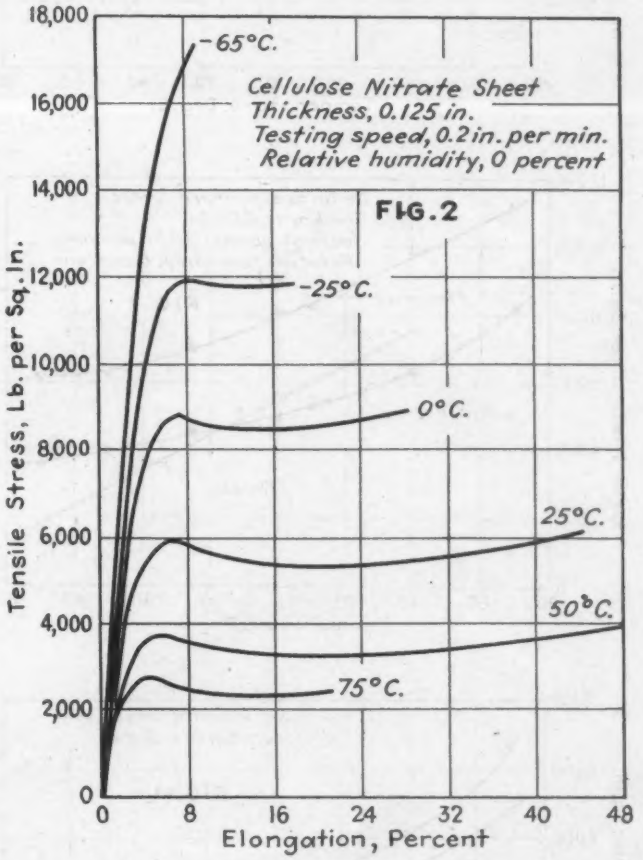
Gages — Watson-Stillman Co., Roselle, N. J. Bulletin 230-A, 4 pages. Describes and illustrates details of the company's hydraulic gages.

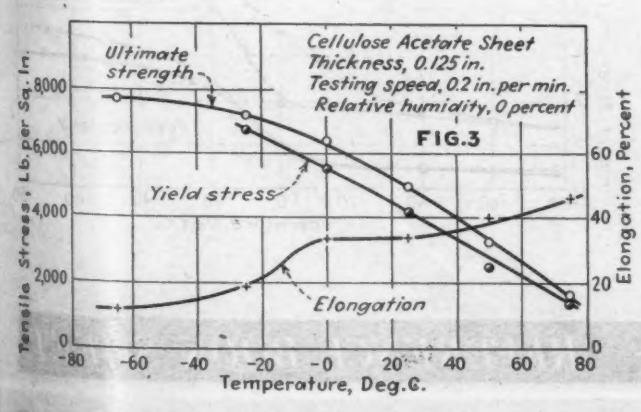
Fastenings—Progressive Mfg. Co., Torrington, Conn. Catalog No. 18, 16 pages. Data about stove bolts, machine screw and stove-bolt nuts, machine screws and special fastenings made by the company are given.

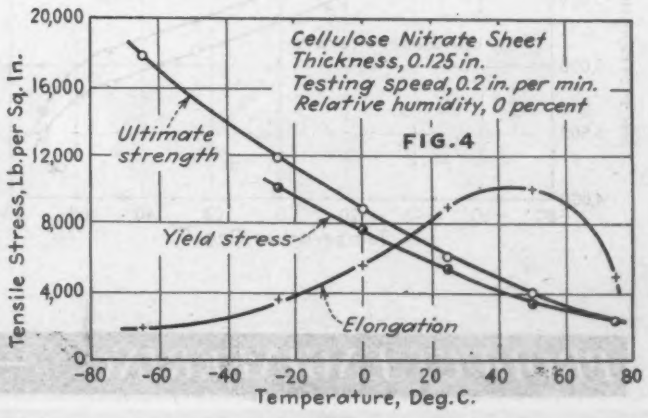
Effect of Temperature On Properties of Plastic Sheets

HOWARD NASON *and* DAVID TELFAIR
Research Department, Plastics Div., Monsanto Chemical Company



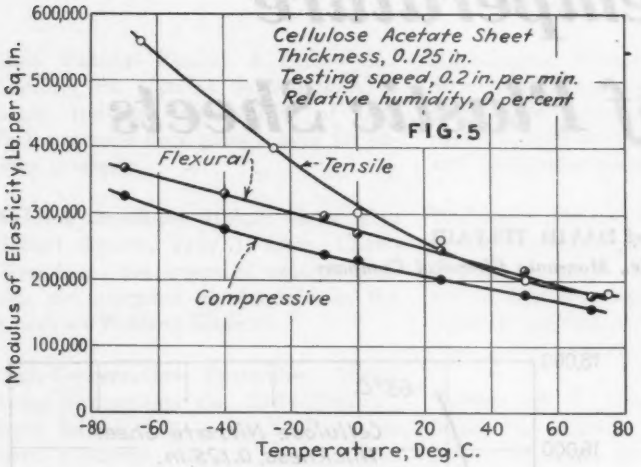


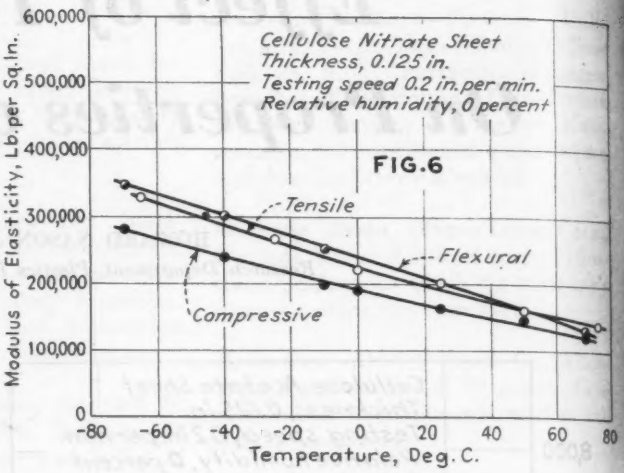


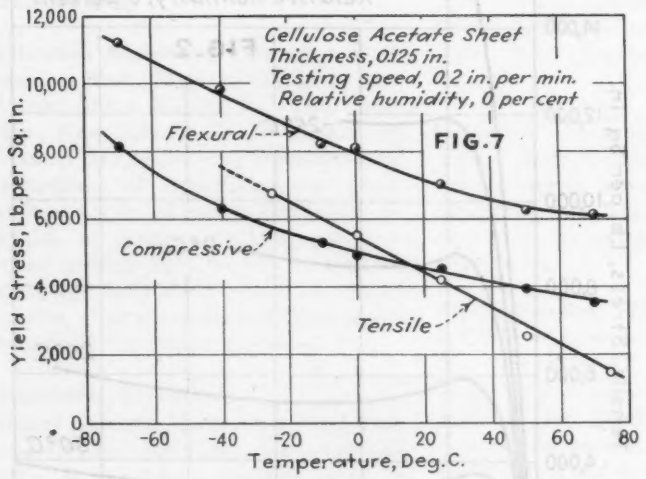


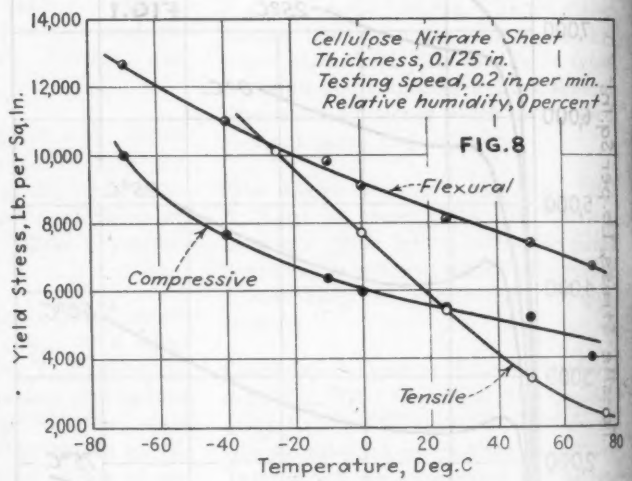
Effect of Temperature

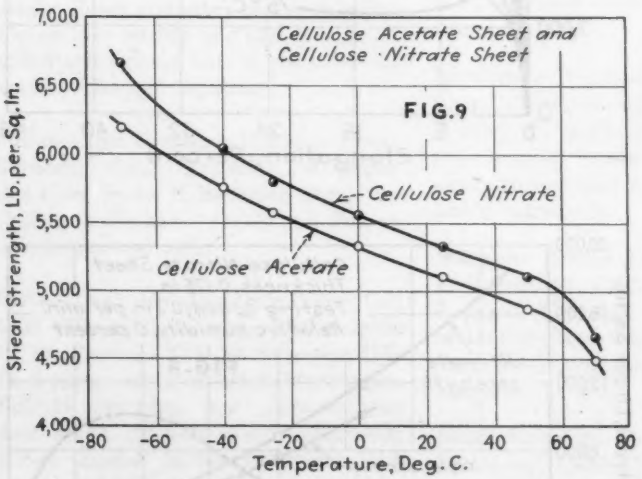
On Properties of Plastic Sheets (continued)

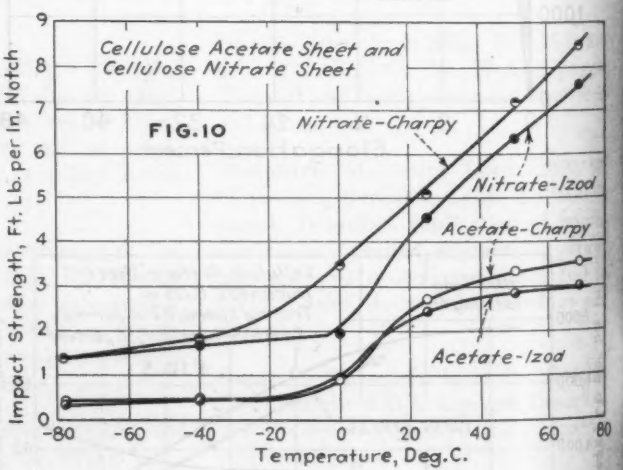












PRODUCT ENGINEERING — REFERENCE BOOK SHEET